FM 24-18

DEPARTMENT OF THE ARMY FIELD MANUAL

FIELD RADIO TECHNIQUES

HEADQUARTERS, DEPARTMENT OF THE ARMY
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FIELD RADIO TECHNIQUES

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CHAPTER 1

INTRODUCTION

Section I. GENERAL

1. Purpose

This manual is a guide for field radio personnel in the employment of radio communication equipment under tactical conditions.

2. Scope

a. This manual covers the fundamentals of radio communication, power supplies, radio-wave propagation and antennas, operating techniques under normal field conditions, operating techniques under unusual conditions, communication security, and maintenance procedure.

b. This manual contains five appendixes and a glossary of radio terms. Appendix I is a list of reference publications and training films; appendix II, Half-Wave Antenna Lengths; appendix III, Types of Emission; appendix IV, Joint Electronics Type Designation System; and appendix V, Technical and Tactical Considerations in Field Radio Communications.

c. The information presented in this manual is applicable without modification to both nuclear and nonnuclear warfare.

3. Comments and Recommendations

Users of this publication are encouraged to submit comments or recommended changes for the improvement of the manual. Comments should be keyed to the page, paragraph, and line of the text to which they apply. Reasons for the comments should be included to insure complete understanding and proper evaluation. Comments should be forwarded to the Commandant, United States Army Signal Center and School, ATTN: Training Literature Division, Fort Monmouth, N.J.

4. Equipment References

Department of the Army Pamphlet (DA Pam) 310–4 is the index of military publications on military equipments. Each communications officer should check this index periodically to deter-

mine if any changes or revisions have been made to the literature covering his equipment.

Section II. EMPLOYMENT OF RADIO COMMUNICATIONS

5. General

a. Radio is the principal means of communication in many tactical units. It is used for command, fire control, exchange of information, administration, and liaison between and within units (fig. 1). It is also used for communication between aircraft in flight, and between aircraft and ground units.

b. Radio communication is particularly adaptable to rapidly changing situations. Communication with highly mobile unts, such as ships, aircraft, and tanks, would be extremely difficult if radio communications were not available.

c. Radio is essential for communication over large bodies of water, over territory controlled by enemy forces, and over terrain where construction of wire lines is impossible or impractical.

6. Capabilities and Limitations

a. Capabilities.

(1) Radio communication facilities usually can be installed more quickly than wire communication facilities; therefore, radio is used extensively as a primary means of communication during the initial stages of combat operations and during fast-moving tactical situations.

(2) Once installed in a vehicle, radio equipment is ready for use and does not require reinstallation.

(3) Radio is mobile. It can be used readily by aerial, amphibious, vehicular, and dismounted units.

(4) Radio lends itself to many modes of operation, such as voice, radiotelephone, radiotelegraph, radio teletypewriter (RATT), visual presentations, and transmission and reception of digital data.

(5) Natural obstacles, minefields, and terrain under enemy control or fire do not limit radio to the same extent that they limit other means of communication. In radio communications, except where a remote capability is employed, no wire is used between the point where information originates and the point to which information is sent. Instead, the connecting link takes the form of electromagnetic waves in space.

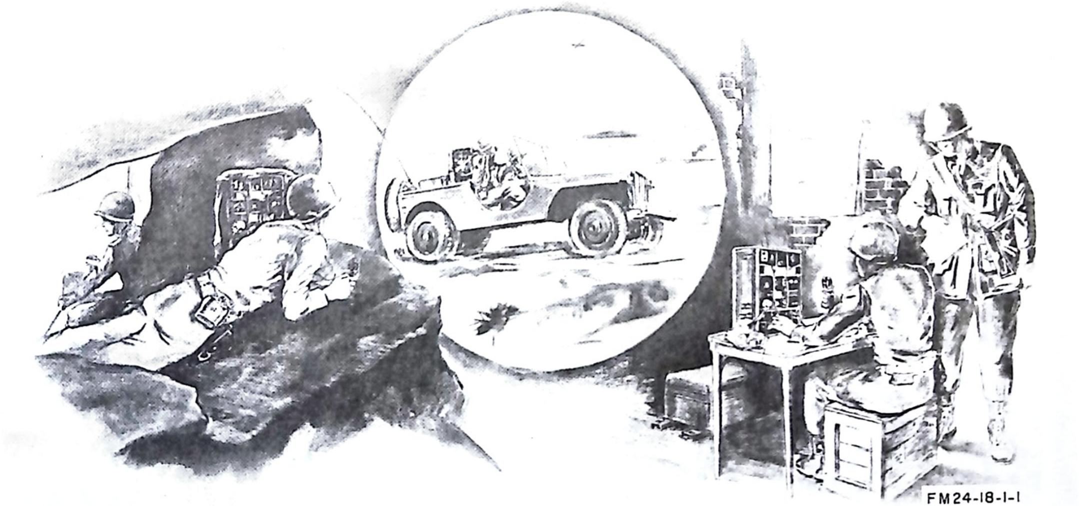

Figure 1. Field applications of radio.

(6) Through the use of remote control equipment, a radio operator may be located at some distance from the set he operates. This provides security for the operator, the radio station, and the command post (CP) served by the radio station.

b. Limitations.

(1) Radio is subject to equipment breakdown, to interference from atmospheric conditions, and to interference from other electronic devices. Also, it is relatively easy to jam.

(2) To be capable of operating together, radios must have common or at least some overlapping frequencies, must transmit and receive the same type signal, and must be located within operating range.

(3) Radio is the least secure means of communication, and it must be assumed that interception occurs every time a transmitter is placed in operation. The enemy obtains information merely by knowing that radios are operating. His analysis of the number of radios in operation, the volume of traffic, or the location is particularly valuable as intelligence.

7. Tactical Application

The extent to which radio is used in combat operations depends on the requirements for secrecy and surprise as balanced against the urgency for radio communication. When surprise is important, radio operation is limited initially to those units already in contact with the enemy. In some instances, to increase deception and surprise, the operation of dummy stations may be directed by higher commanders. When a unit is moving into an area just prior to attack, it may be directed to maintain listening silence until the attack is launched. When a unit is already occupying a sector from which it is to launch an attack, and its radio stations are in operation, it may be directed to maintain normal radio operations without substantial change in traffic load until the attack is launched. If a unit is moved to another sector or is relieved by another unit, it may be required to provide dummy radio stations to continue operations until the attack is fully under way. Once the attack is launched, special restrictions on radio operations are generally removed.

CHAPTER 2

FUNDAMENTALS OF RADIO COMMUNICATION

Section I. ELEMENTS OF TRANSMISSION AND RECEPTION

8. Radio Equipment

A radio set consists essentially of a *transmitter* that generates radio frequency (RF) energy; a source of electrical power; a *key, microphone,* or *teletypewriter,* that controls these energy waves; a *transmitting antenna* that radiates RF waves; a *receiving antenna* that intercepts some of the radiated RF waves; a source of electrical power; a *receiver* that converts intercepted RF waves into usable energy (usually audio frequency (AF) energy); and a *loudspeaker, headphones,* or *teletypewriter* provide intelligibility. When the frequency coverage of two sets is similar, when they have the same modulation, and the distance between them does not exceed the range of the equipment, two-way communication using electromagnetic (radio) waves is possible. Figure 2 is a block diagram of a basic radio set.

9. Radio Transmitter

The simplest radio transmitter (fig. 3) consists of a power supply and an oscillator. The power supply can be batteries, a generator, an alternating-current (AC) power source, including

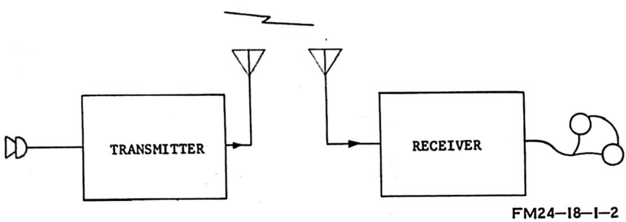

Figure 2. Block diagram of basic radio set.

a rectifier and filter or a direct-current (DC) rotating power source. The oscillator, which generates RF alternating current, must contain a tuned circuit to tune the transmitter to the desired operating frequency. The transmitter must also have some device for controlling the generated RF energy. The simplest device is a telegraph key, which is merely a type of switch for controlling the flow of electric current. When the key is operated, the oscillator is turned on and off for varying lengths of time to form dots and dashes of RF energy.

10. Continuous-Wave Transmitter

Since the RF power generated by an oscillator is normally neither stable enough nor great enough to provide reliable transmission over long distances, an RF amplifier (fig. 4) is added after the oscillator to develop a more stable and higher power output. If only code transmission is desired, this type transmitter is entirely satisfactory.

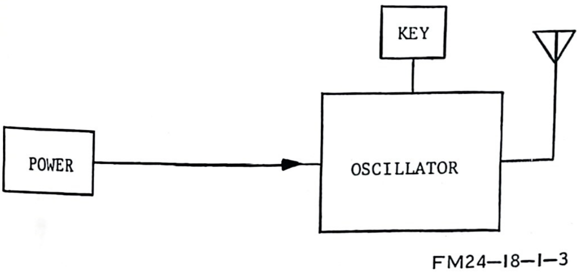

Figure 3. Block diagram of a simple radio transmitter.

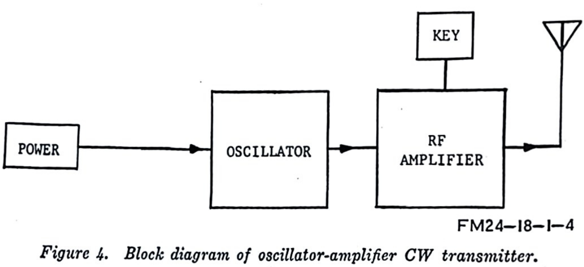

Figure 4. Block diagram of oscillator-amplifier CW transmitter.

11. Radiotelephone Transmitter

To transmit messages by voice, it is necessary to have some means of controlling the output of the transmitter in accordance with the voice frequencies (audio frequencies). This is accomplished by a modulator, which changes the output of the transmitter in accordance with the voice frequencies; this process is known as *modulation* and an RF wave affected in this manner is called a *modulated wave.* When the modulating signal causes the amplitude of the radio wave to change, the process is called *amplitude modulation* (AM). When the modulating signal varies the frequency of the radio wave, the process is called *frequency modulation* (FM). In figure 5, a modulator and a microphone are added to the radiotelegraph transmitter to change it to an amplitude-modulated radiotelephone transmitter.

12. Antennas

After an RF signal has been generated and amplified in the transmitter, a means must be provided to radiate this RF energy into space. At the same time, a means must be provided at the

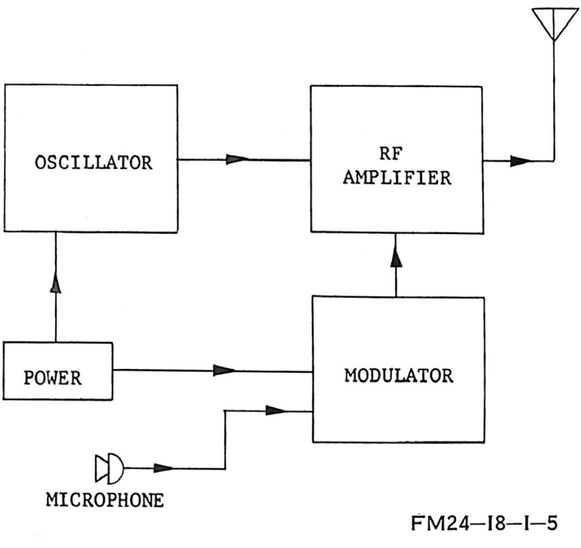

Figure 5. Block diagram of radiotelephone transmitter.

receiver location to intercept (pick up) the signal. The device that fulfills these requirements is called an *antenna*. The *transmitting antenna* sends transmitter signal energy out into space; this energy, radiated in the form of electromagnetic waves, is intercepted by a *receiving antenna*. If the receiver is tuned to the same frequency as the transmitter, the signal will be received and intelligible information made available.

13. Radio Receiver

a. Detector (Demodulator). There are two general kinds of RF signals that can be received by a radio receiver: modulated RF signals that carry speech, music, or other audio energy, and continuous wave (CW) signals that are *bursts* of RF energy conveying intelligence by means of code (dot) signals. The process whereby the intelligence carried by an RF signal is extracted is called *detection* or demodulation. The circuit used to accomplish this is called a detector (fig. 6), since it actually detects the incoming intelligence. The receiver must have some means of tuning in, or selecting, the frequency of the desired RF signal. This selective action is necessary to avoid the detection of many RF signals of different frequencies at the same time. That part of the detector which is used to tune in the desired signal is called a tuned circuit. In FM radio receivers, the detector is known as a discriminator.

b. RF Amplifier. Because an RF signal diminishes in strength or amplitude at a very rapid rate after it leaves the transmitting antenna and because many RF signals of various frequencies are crowded into the radio frequency spectrum, a detector is not used alone. An RF amplifier (fig. 7) is included in the receiver to increase the sensitivity (ability to receive weak signals) and the

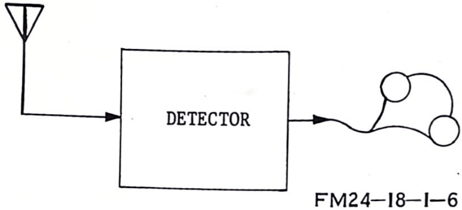

Figure 6. Block diagram of simple radio receiver.

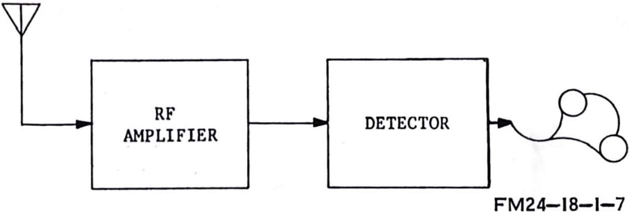

Figure 7. Block diagram of detector and RF amplifier.

selectivity (ability to separate signals of different radio frequencies). The RF amplifier is provided with one or more tuned circuits so that the desired RF signal (the one to which it is tuned) is amplified more than RF signals of other frequencies.

c. AF Amplifier. The power output of a detector, with or without an RF amplifier, is generally too little to be useful. One or more AF amplifiers (fig. 8) therefore are added to the receiver to increase the AF power to a level that will operate headphones, a loudspeaker, or teletypewriter equipment.

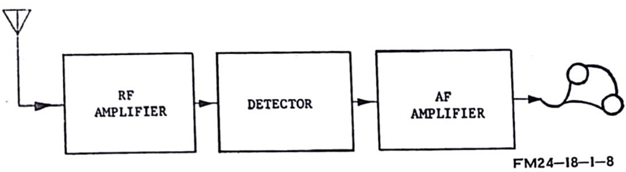

Figure 8. Block diagram of complete radio receiver.

Section II. RADIO WAVES

14. General

Radio waves travel near the surface of the earth and also radiate skyward at various angles to the earth's surface (fig. 9). These electromagnetic waves travel through space at the speed

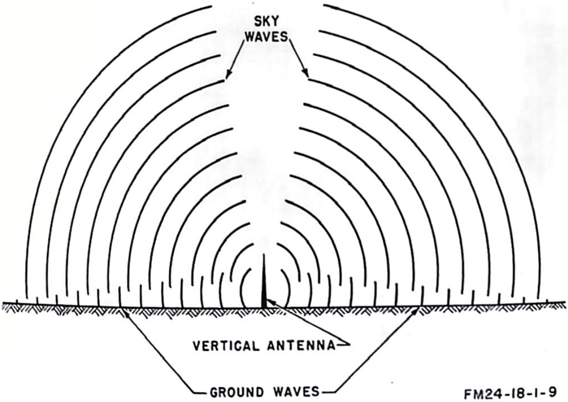

Figure 9. Radiation of radio waves from a vertical antenna.

of light, approximately 186,000 miles (300,000 kilometers (KM)) per second.

15. Wavelength

The length of a radio wave is the distance traveled by the wave in the period of time required to complete one cycle. Each complete cycle of 2 alternations of the wave (fig. 10) is 1 wavelength and is expressed in meters. This wavelength may be measured from the start of one wave to the start of the next wave, or from the crest of one wave to the crest of the next wave. In either case the distance is the same.

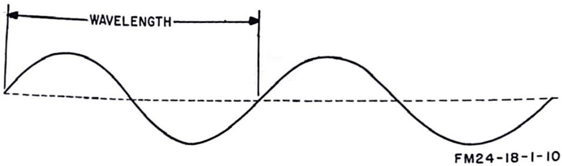

Figure 10. Wavelength of a radio wave.

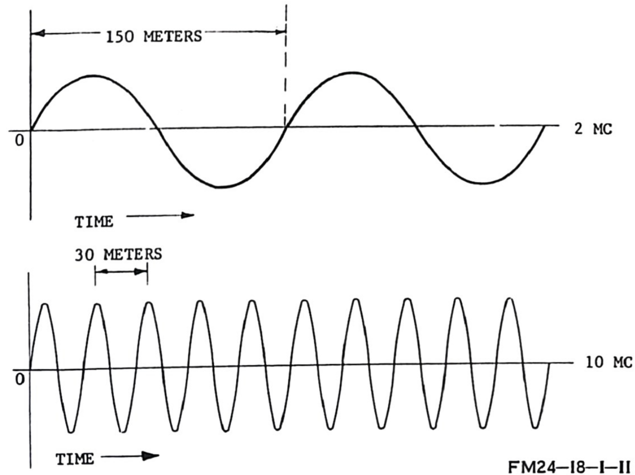

Figure 11. Comparison of two waves of different frequency.

16. Frequency

a. The frequency of a radio wave is the number of complete cycles that occur in one second. The longer the time of one cycle, the longer the wavelength and the lower the frequency. The shorter the time of one cycle, the shorter the wavelength and the higher the frequency. Figure 11 compares the wavelength of a 2–MC wave with that of a 10–MC wave.

b. Since the frequency of a radio wave is very great, it is expressed in kilocycles per second (KC) or megacycles per second (MC). One KC is equal to 1,000 cycles per second, and 1 MC is equal to 1,000,000 cycles per second.

c. For practical purposes, the velocity of a radio wave is considered to be constant, regardless of the frequency or the amplitude of the transmitted wave. Therefore, to find the wavelength when the frequency is known, divide the velocity by the frequency.

$$\text{Wavelength (in meters) (free space)} = \frac{300{,}000{,}000 \text{ (meters per second)}}{\text{frequency (cycles per second)}} = \frac{300{,}000}{\text{frequency (KC)}} = \frac{300}{\text{frequency (MC)}}$$

d. To find the frequency when the wavelength is known, divide the velocity by the wavelength.

$$\text{frequency (cycles per second)} = \frac{300{,}000{,}000}{\text{wavelength (meters)}}$$

$$\text{frequency (KC)} = \frac{300{,}000}{\text{wavelength (meters)}}$$

$$\text{frequency (MC)} = \frac{300}{\text{wavelength (meters)}}$$

17. Frequency Bands

Most tactical radio sets operate within the 1.5 MC to 400 MC portion of the frequency spectrum. Radio frequencies are divided into groups or bands of frequencies for convenience of study and reference. The frequency bands of the radio spectrum are shown in the following chart.

Band	Frequency (MC)
Very low frequencies (VLF)	Below .03
Low frequency (LF)	.03 to .3
Medium frequency (MF)	.3 to 3.0
High frequency (HF)	3.0 to 30
Very high frequency (VHF)	30 to 300
Ultrahigh frequency (UHF)	300 to 3,000
Superhigh frequency (SHF)	3,000 to 30,000
Extremely high frequency (EHF)	30,000 to 300,000

18. Characteristics of Frequency Bands

The data in the chart below, which are approximate under normal operating conditions, indicate that each frequency band has certain transmission characteristics. The exact characteristic depends upon the condition of the propagation medium, the transmitter power output, and many other factors.

Band	Range				Power required (KW)
	Ground waves		Sky waves		
	Miles	KM	Miles	KM	
LF	0 to 1000	0 to 1609	500 to 8000	835 to 12,872	above 50
MF	0 to 100	0 to 161	100 to 1500	161 to 2415	[b].5 to 50
HF	0 to 50	0 to 83	100 to 8000	161 to 12,872	.5 to 5
VHF	0 to 30	[a]0 to 48	[a]50 to 150	[a]83.5 to 241	.5 or less
UHF	0 to 50	0 to 83	----------	-------------	.5 or less

[a] Troposcatter or ionospheric scatter provides this range.
[b] Troposcatter or ionospheric scatter requires this power range.

Section III. METHODS OF TRANSMISSION

19. General

a. The radio communication equipment in lower echelon units is used primarily to transmit intelligence in the form of speech or telegraphic code.

b. When audio-frequency vibrations (speech or telegraphic code) activate the ear drum, the effect on the human nervous system is called *sound.* This form of acoustical energy travels through the air at a velocity of approximately 1,100 feet per second.

c. Although sound can be converted to audio-frequency electrical energy, it is not practical to transmit it in this energy form through the earth's atmosphere by electromagnetic radia-

tion. For example, efficient transmission of a 20-cycle audio signal would require an antenna almost 5,000 *miles* long.

d. None of the above limitations apply when radio-frequency electrical energy is used to carry the intelligence. Tremendous distances can be covered; efficient antennas for radio frequencies are of practical lengths; antenna power losses are at reasonable levels; many channels, each carrying information, can be used; and selectivity of information is possible.

20. Modulation

a. Since the carrier wave (fig. 12) itself does not convey intelligence, information in the form of a signal wave is superimposed upon the carrier. This process, which is called *modulation,* varies or modifies either the frequency or the amplitude of the carrier waveform. Both *amplitude modulation* and *frequency modulation* methods are used in military radio communication systems.

b. When AF signals are superimposed on the RF carrier, additional RF signals are generated. The additional frequencies are equal to the sum and difference of the audio frequencies and the radio frequency involved. For example, assume that a 1000-KC carrier is modulated by a 1 KC audio tone. Two new radio frequencies are developed, one at 1001 KC (the sum of 1000 and 1 KC) and the other at 999 KC (the difference between 1000 and 1 KC). If a complex audio signal is used instead of a single tone, two new frequencies will be set up for each of the audio frequencies involved. The new frequencies are called sidebands.

21. Amplitude Modulation (AM)

Amplitude modulation is defined as the variation of the RF power output of a transmitter at an audio rate. In other words, the RF energy increases and decreases in power according to the audio (sound) frequencies. In very simple terms, amplitude modulation is the process of varying the power output of a transmitter (fig. 12).

a. When an RF carrier is modulated by a single audio tone, two additional frequencies are produced. One is the *upper frequency,* which equals the sum of the frequency of the RF carrier and the frequency of the audio note. The other is the *lower frequency,* which equals the difference between the frequency of the RF carrier and the frequency of the audio note. The one higher than the carrier frequency is the *upper side frequency;* the one lower than the carrier frequency is the *lower side frequency.*

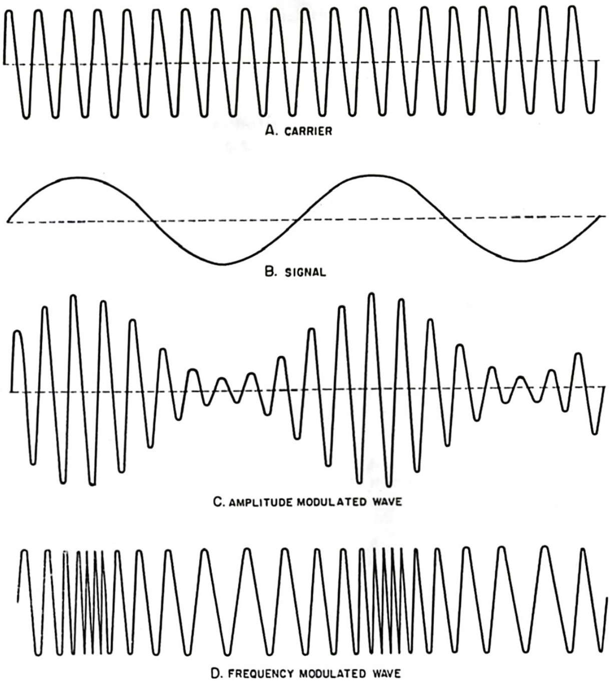

Figure 12. Wave shapes.

b. When the modulating signal is made up of complex tones, as in speech, each individual frequency component of the modulating signal produces its own upper and lower side frequencies. These side frequencies occupy a band of frequencies called *side bands.* The side band that contains the sum of the carrier and modulating frequencies is called the *upper side band;* the side band that contains the difference of the carrier and the modulating frequencies is called the *lower side band.*

c. The space that a carrier and its associated side bands occupy in a frequency spectrum is called a *channel.* In amplitude modulation, the width of the channel (bandwidth) is equal to twice the highest modulating frequency. Consequently, if a 5,000-KC carrier is modulated by a band of frequencies ranging from 200

to 5,000 cycles (.2 to 5 KC), the upper side band extends from 5,000.2 to 5,005 KC, and the lower side band extends from 4,999.8 to 4,995 KC. The bandwidth is then 10 KC, which is twice the highest modulating frequency (5 KC).

d. The intelligence of an amplitude-modulated signal exists solely in the side bands, the amplitude of which vary according to the strength of the modulating signal.

e. Amplitude modulation generally is used by radiotelephone transmitters operating in the medium and high frequency portions of the spectrum.

22. Frequency Modulation (FM)

Frequency modulation is the process of varying the frequency (fig. 12) of the carrier wave.

a. In a frequency-modulated wave, the frequency varies instantaneously about the unmodulated carrier frequency in proportion to the amplitude of the modulating signal. When the modulating signal increases in amplitude, the instantaneous frequency increases; when the modulating signal decreases, the frequency decreases.

b. In an FM wave, the amplitude of the modulating signal determines the extent of departure of the instantaneous frequency from the center, or rest, frequency. Thus, the instantaneous frequency can be made to deviate as much as desired from the carrier frequency by changing the amplitude of the modulating signal. This deviation frequency may be as high as several hundred kilocycles, even though the modulation frequency is only a few kilocycles. The side-band pairs generated by frequency modulation are not restricted, as in amplitude modulation, to the sum and difference between the highest modulating frequency and the carrier.

c. The first pair of side-band pairs in an FM signal are those of the carrier frequency plus and minus the modulating frequency. Additional side-band pairs will appear at each multiple of the modulating frequency. For example, if a carrier of 1 MC is frequency modulated by an audio signal of 10 KC, there will be several side-band pairs, spaced equally on either side of the carrier frequency at 990 KC and 1,010 KC, at 980 KC and 1,020 KC, at 970 KC and 1,030 KC, and so on. As a result, a frequency-modulated signal occupies a greater bandwidth than does an amplitude-modulated signal.

d. As indicated above, the FM wave consists of a center or carrier frequency and a number of side-band pairs. When modulation

is applied, and the amplitude of the modulating signal is increased, power is taken from the center-frequency component and forced into the side-band pairs.

e. The FM signal leaving the transmitting antenna is constant in amplitude, but varying in frequency according to the audio-modulating signal. As the signal travels between the transmitting and receiving antennas, however, it is combined with natural and manmade noises that cause amplitude variations in the signal. All of these undesirable amplitude variations are amplified as the signal passes through successive stages of the receiver until the signal reaches the limiter stage.

f. The limiter eliminates amplitude variations and passes the FM signal on to the discriminator, which is sensitive to variations in the frequency of an RF wave. The resultant constant-amplitude, frequency-modulated signal then is processed by the discriminator circuit, which transforms the frequency variations of the signal into corresponding voltage amplitude variations. These voltage variations reproduce the original modulating signal in a reproducing device, such as a headset, loudspeaker, or teletypewriter.

g. Frequency modulation generally is used by radiotelephone transmitters operating in the VHF and higher frequency bands.

23. Single Sideband

a. Only one of the two sidebands that are part of an amplitude-modulated signal appear in the spectrum of a single sideband (SSB) signal. Figure 13 shows the theoretical distribution of power in an AM signal. Figure 14 shows that a single sideband transmitter with the same power capability filters one sideband, suppresses the carrier, and makes the filtered sideband power and the suppressed carrier power available to increase the transmitted power of the remaining sideband.

b. Because an SSB signal is produced through a mixing operation, both sum and difference frequencies are developed. Both these upper sideband frequencies and lower sideband frequencies contain the same modulating intelligence; the choice of sideband transmitted depends on the characteristics of the sideband filter employed. Transmission of one sideband leaves open that portion of the RF spectrum normally occupied by the other sideband of an AM signal. For further information on SSB, refer to TM 11–685.

24. Radiotelegraphy

a. Radiotelegraph information can be transmitted by starting and stopping the carrier wave means of a switch, or key. The

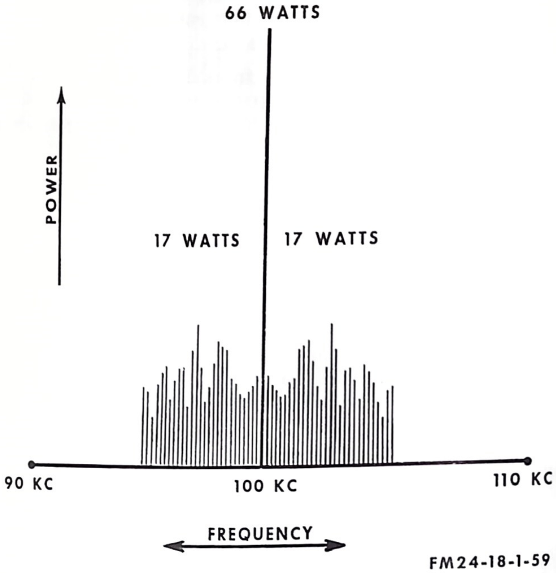

Figure 13. Power distribution in an AM signal.

individual letters and numbers of a message are indicated by combining short and long pulses (dots and dashes) in groups according to the radiotelegraph code. For example, if the operator wishes to send the letter A in code (fig. 15), he closes the key for a fraction of a second, opens it for the same length of time, then closes it again for a period three times the length of the first. This process of transmitting information, called *radiotelegraphy* or *continuous wave* transmission, is illustrated by the waveforms in figure 15.

b. Radiotelegraph information can also be transmitted by using a tone-modulated wave. In tone transmission, the carrier is modulated at a fixed audio rate between 500 and 1,000 cycles per second. Because tone emission is broad, it may be used successfully against some types of jamming. Also, the broad signal is an easy target for radio direction-finders. The distance range of a tone-modulated transmitter is less than that of a CW transmitter of the same power output.

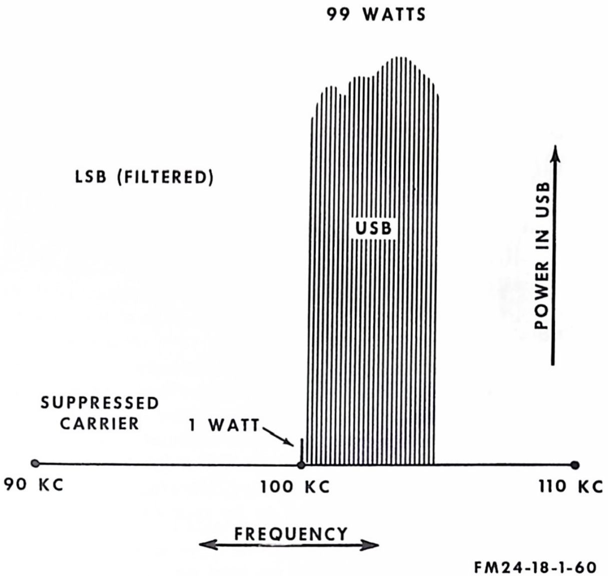

Figure 14. Single sideband transmission.

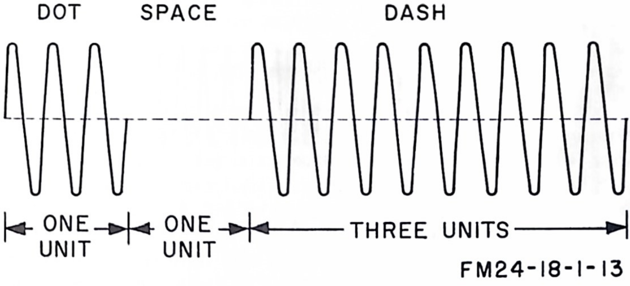

Figure 15. CW signal.

c. Manual radiotelegraph transmission has limited traffic-handling capacity. Consequently, its use is confined to lower echelons of the army, where the traffic load is light. It may also

be used in isolated or remote locations, if other means of communication are not available.

(1) Radiotelegraph communications can often be used when other types of radio communication fail because of atmospheric conditions or interferences.

(2) Radiotelegraph transmitters have a greater transmission range than radiotelephone transmitters of the same output power because the power containing the intelligence is concentrated in a much narrower bandwidth.

(3) Within a given frequency band, it is possible to operate without interference many more radiotelegraph transmitters than radiotelephone transmitters.

25. Radiotelephony

a. A microphone of a radiotelephone set converts voice or sound waves (fig. 16) to weak electrical impulses. These impulses are strengthened by passing them through a series of audio amplifiers and then through a modulator. The modulator provides the audio power necessary to modulate the RF amplifier. At the receiver, the modulated RF is demodulated, allowing only the audio component of the incoming signal to be reproduced by a loudspeaker or headset.

b. Radiotelephone transmission is used extensively for communication with highly mobile combat units, where speed of transmission is essential. It is used for person-to-person contact, where security is not a limiting factor.

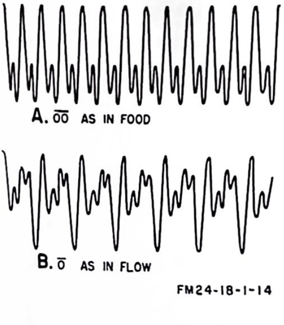

Figure 16. Examples of voice-sound waves.

26. Radio Teletypewriter

a. Radio teletypewriter transmission is possible over distances of up to several thousand miles. This type of transmission is often used by higher echelons in rapidly changing tactical situations where time does not permit the installation of wire facilities, and in areas where traffic loads are heavy and radio circuits are reliable. It is also of great value between points that are not easily connected by wire lines, such as those separated by large bodies of water or jungle areas.

b. The teletypewriter itself consists of a transmitting keyboard and a receiving and printing mechanism. The depression of a key releases the transmitting mechanism and sends a series of electrical impulses over a radio channel to a receiving device. This device translates the impulses into a mechanical action so that the printer may select and print the proper character. Each key sends a different arrangement of pulses (fig. 17), and the message may be printed in page form, or on a tape. The teletypewriter keyboard contains the letters of the alphabet, and punctuation marks (fig. 17). The machines will also perform the functions of carriage return, line feed, letter shift, figure shift, and space.

c. In the special signaling code used for teletypewriter transmission, each character or signal is of uniform length and consists of five intervals of time. The units are equal in length and are known as either marking or spacing impulses in the circuit. A marking impulse (mark) exists when current flows in the circuit and the selector magnets in the receiving printers are operated. A spacing impulse (space) is the open condition in the circuit when selector magnets in the receiving printers are not operated. Various combinations of marking and spacing impulses are used for different letters in the alphabet, numerals, and functions.

d. In the most commonly used method of operation, the teletypewriter signals key a radio transmitter which, in turn, radiates on one frequency for the marking condition and on a slightly different frequency for the spacing condition. This type of operation, which is a form of frequency modulation, is called frequency shift keying (FSK). The radio receiver converts the two frequencies, which are 850 cycles apart, back into teletypewriter pulses. The pulses then cause the receiving teletypewriter to operate. The striking of a key on the transmitting teletypewriter will, therefore, activate the corresponding character on the receiving teletypewriter.

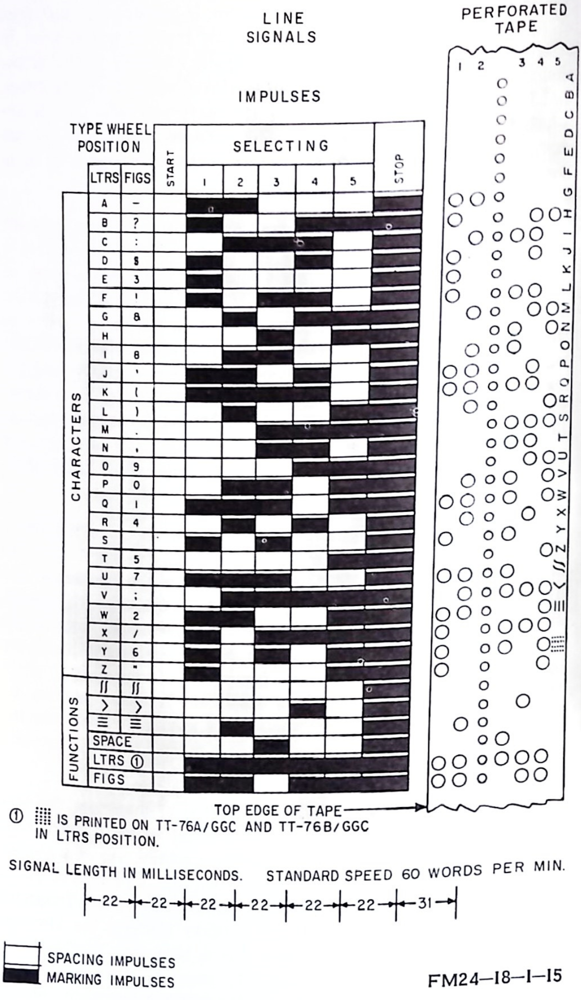

Figure 17. Standard start-stop, five-unit code chart.

CHAPTER 3

POWER SOURCES

27. General

The power required to operate radio equipment may come from a variety of sources, such as commercial power, dry batteries, storage batteries, engine-driven generators, and rectifiers. Each type has certain advantages and certain limitations. Depending upon the application involved, these sources of power may be used individually or in combinations.

28. Commercial Power

Various values of alternating-current (AC) and direct-current (DC) voltages can be obtained from commercial power lines and used as primary power sources. The AC voltage sources range from the standard 115-volt, single-phase power source to the 2,300-volt, three-phase power used for industrial purposes. The primary DC voltage sources range from 32 to 440 volts. Power supplies designed for AC operation must not be connected to a DC source, since this will damage the power transformer. Also, equipment designed exclusively for a DC source will not operate on AC power.

29. Power Converters

Because of the wide variation in commercial power in various parts of the world, and because of the special power requirements of certain types of communication equipment, it is frequently necessary to make changes in the available power. It may be desired to convert AC to DC, or DC to AC. It may be necessary to provide 60-cycle current from a 25-cycle power source, step the voltage up or down, or convert single-phase power to multiphase power. Vibrators, dynamotors, rotary converters, motor generators, or transformers may be used singly or in combination to effect these changes. The choice of equipment depends on the desired result and the amount of power to be handled.

a. Transformers. Most AC devices for communication systems are designed to operate at 50 to 60 CPS from a 115- or 230-volt power source. In many areas, however, the available voltage is unsuitable for the operation of such equipment. Therefore, power transformers are used to increase or decrease the AC input voltage to the values required.

b. Vibrators. Vibrators are used in vehicular power units to convert direct current from a low-voltage power source, such as a 6-, 12-, or 24-volt storage battery, into alternating current that can be rectified to provide the higher DC potentials required by radio equipment. Vibrators convert the low DC voltages to pulsating voltages that can then be stepped up to higher voltages by applying them to special step-up power transformers.

c. Dynamotors. Dynamotors are rotating machines used to convert DC voltage of one value (6, 12, or 24 volts) to DC voltage of another value (several hundred or more volts).

d. Rotary Converters. Rotary converters are synchronous machines that convert AC of one voltage and frequency to AC of another voltage and frequency. They may also be used to convert AC to DC and DC to AC. The machine that converts DC to AC is known as an inverted converter or inverter.

e. Motor Generator. The function of the motor generator is similar to that of a rotary converter.

30. Dry Batteries

Dry batteries are especially adapted for use where small amounts of power are needed and portability is required. Normally they are used to supply power for field telephones, portable radio transmitters and receivers, power alarm circuits and emergency signal lights, and portable test equipment. They are produced in various sizes and shapes, and in several capacities and voltages, to accommodate this wide range of uses.

31. Lead Storage Batteries

Lead storage batteries provide a compact source of DC for operation of transportable (tactical) telephone exchanges and various radio transmitters and receivers. They are also used in vehicular ignition systems. In addition, they furnish primary power to crank gasoline and diesel engines on engine-generator sets up to 50 KW.

32. Engine-Driven Generator Units

DC engine-driven generators have output capacities of from 0.4 to 15.0 KW. AC engine-driven generators have output capacities of from 0.3 to 1,000 KW. In addition, there are certain special purpose generators that provide both AC and DC output.

CHAPTER 4

PROPAGATION OF RADIO WAVES

33. The Atmosphere

Wave propagation deals with the properties and the nature of the atmosphere through which radio waves must travel from the transmitting antenna to the receiving antenna. The atmosphere is not uniform, but varies with the altitude, geographic location, time of day or night, season, and year. A knowledge of the composition and properties of the atmosphere aids in the solution of problems that arise in planning radio communication paths and in predicting the reliability of communications.

a. Troposphere. The troposphere is that portion of the earth's atmosphere extending from the surface of the earth to heights of approximately 6½ miles (10 KM). Within the troposphere, the bending of radio waves by refraction causes the radio horizon to exceed the optical horizon. Tropospheric refraction (reflection caused by sudden changes in the characteristics of air in a lower atmosphere) affect the received signal at distances beyond the radio horizon.

b. Stratosphere. The stratosphere is that portion of the earth's atmosphere lying between the troposphere and ionosphere, about 6½ miles to 30 miles (10 to 48 KM) above the earth. The temperature in this region is nearly constant.

c. Ionosphere. The ionosphere is that portion of the earth's atmosphere above the lowest level at which ionization (splitting of molecules into positive and negative charges, or ions) of low-pressure gasses will affect the transmission of radio waves. It extends from about 30 to 250 miles (48 to 402 KM) above the earth. The ionosphere is composed of several distinct layers in which ionization occurs at different levels and intensities.

34. Propagation in the Atmosphere

There are two principal paths by which radio waves can travel from a transmitter to a receiver. One is by ground waves (fig. 18), which travel directly from the transmitter to the receiver.

The other is by sky waves (fig. 18), which travel up to the ionosphere and are bent downward, or refracted, back to the earth. Long-distance radio transmission is achieved principally by the use of sky waves. Short-distance and all UHF and upper VHF transmissions are by means of ground waves. Some forms of transmission make use of combinations of both paths.

a. Ground-wave propagation is affected by the electrical characteristics of the earth and by the amount of diffraction, or bending, of the wave around the curvature of the earth. These characteristics vary in different localities, but they are relatively constant with respect to time and the season.

b. Sky-wave propagation is variable, since the constantly changing state of the ionosphere has a definite effect on the refraction of the waves.

35. Ground-Wave Propagation

Ground-wave propagation refers to those types of radio transmission that do not make use of waves that have been refracted

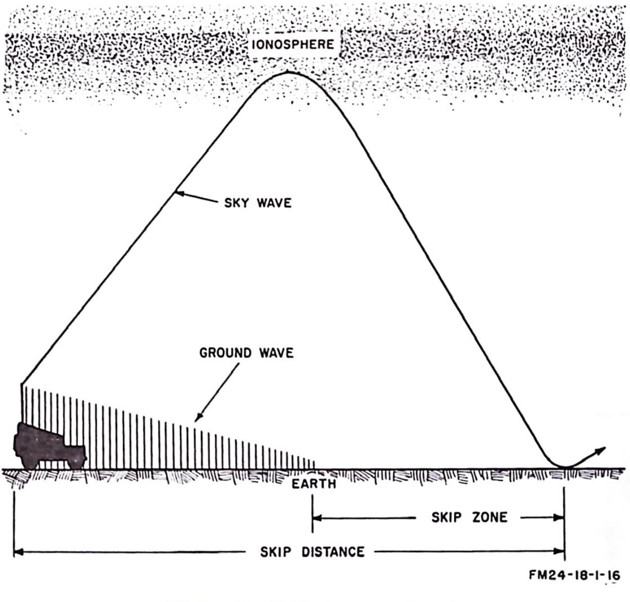

Figure 18. Radio wave components.

from the ionosphere. The field intensity of ground waves depends on the transmitter power, the characteristics of the transmitting antenna, the frequency of the waves, the diffraction of the waves around the curvature of the earth, the electrical characteristics (conductivity and dielectric constant) of the local terrain, the nature of the transmission path, and local weather conditions. The following are the components of a ground wave:

a. Direct Wave. The direct wave is that component of the entire wave front that travels directly from the transmitting antenna to the receiving antenna (fig. 19). This component is limited to the line-of-sight distance between the transmitting and receiving antennas, plus the small distance added by atmospheric refraction and diffraction of the wave around the curvature of the earth. This distance can be extended by increasing the height of either the transmitting antenna or the receiving antenna (or both).

b. Ground-Reflected Wave. The ground-reflected wave (fig. 19), is the portion of the radiated wave that reaches the receiving antenna after being reflected from the surface of the earth. When both the transmitting and receiving antennas are on or close to the ground, the direct and ground-reflected components of the ground wave tend to cancel each other.

c. Surface Wave. The surface wave (fig. 19), which follows the curvature of the earth, is the component of the ground wave that is affected by the conductivity and dielectric constant of the earth.

36. The Ionosphere

There are four distinct layers of the ionosphere. In the order of increasing heights and intensities, they are called the D, E,

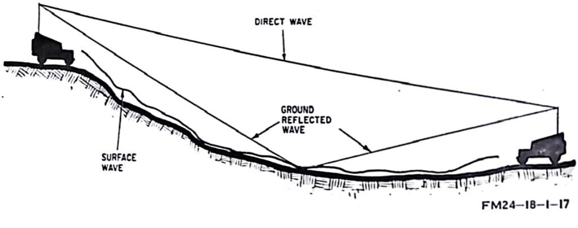

Figure 19. Possible routes for ground waves.

F1, and F2 layers. The relative distribution of these layers is shown in figure 20. As may be seen in the illustration, the four layers are present only during the day when the rays of the sun are directed toward that portion of the atmosphere. During the night, the F1 and F2 layers seem to merge into a single F layer, and the D and E layers fade out. The actual number of layers, their heights above the earth, and the relative intensity of ionization present in them vary from hour to hour, from day to day, from month to month, from season to season, and from year to year.

a. D Region. The D region exists only during daylight hours and has little effect in bending the paths of high-frequency radio waves. The main effect of the D region is to attenuate, or decrease, the intensity of high-frequency waves when the transmission path lies in sunlit regions.

b. E Region. The E region is used during the day for high-frequency radio transmission over intermediate distances (less than approximately 1,500 miles (2400 KM)). The intensity of this layer decreases during the night, however, and it becomes useless for radio transmission.

c. F Layer. The F layer exists at heights up to 240 miles (380 KM) above the surface of the earth and is ionized at all hours of the day and night. There are two well-defined layers during the day and one during the night. At night the F layer lies at a height of about 170 miles (260 KM) and is useful for long-range radio communication (over 1,500 miles (2400 KM)).

d. F1 and F2 Layers. During the day the F region splits up into two distinct layers, the F1 layer and the F2 layer. The F2 layer is the most useful of all layers for long-range radio communication, even though the degree of ionization varies appreciably from day to day as compared with other layers.

37. Ionosphere Characteristics

a. Critical Frequency. The range of long-distance radio transmission is determined primarily by the ionization density of each of the layers. The higher the frequency, the greater the density of ionization required to refract radio waves back to earth. The upper (E and F) layers refract the higher frequencies because they are the most highly ionized. The D layer, which is the least ionized, does not refract frequencies above approximately 500 KC. Thus, at any given time and for each ionized layer, there is an upper frequency limit at which waves sent vertically upward are reflected directly back to earth. This limit is called the *critical*

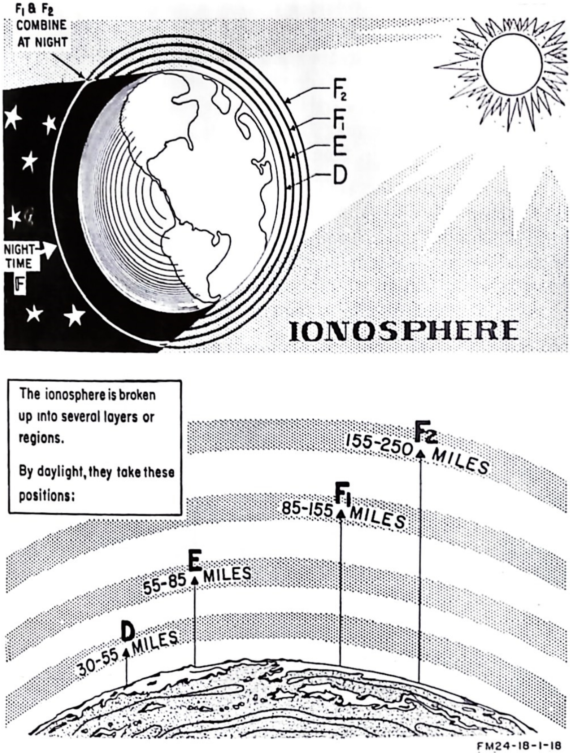

Figure 20. Average layer distribution of the ionosphere.

frequency. Waves directed vertically at frequencies higher than the critical frequency pass through the ionized layer out into space. All waves directed to the ionosphere at frequencies lower than the critical frequency are refracted back to the earth.

b. Critical Angle. Radio waves used in communication generally are directed to the ionosphere at some oblique angle, called the *angle of incidence.* Waves at frequencies above the critical frequency will be returned if propagated at angles of incidence lower than the critical angle. At the critical angle, and at all

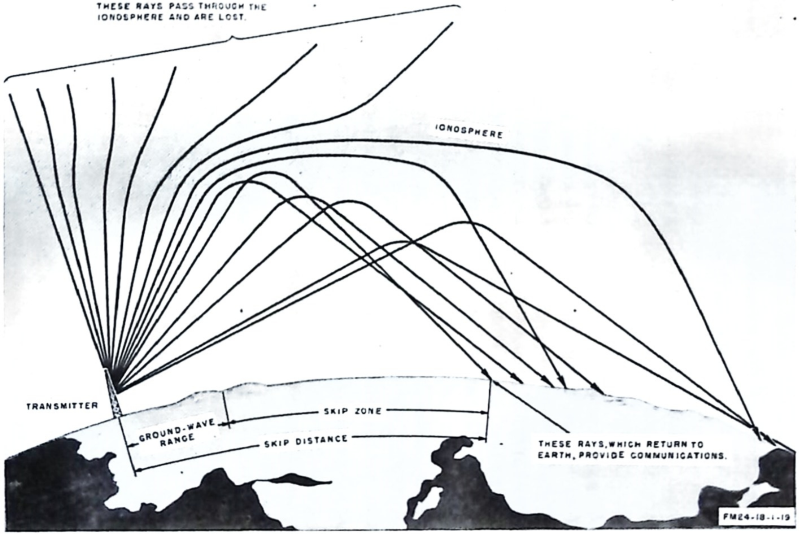

Figure 21. Sky wave transmission paths.

angles larger than the critical angle, the wave will pass through the ionosphere if the frequency is higher than the critical frequency. As the angle becomes smaller, an angle is reached at which the wave is bent back to the earth by refraction. The distance between the transmitting antenna and the point at which the wave *first* returns is called the skip distance (fig. 21).

38. Variations of the Ionosphere

The movements of the earth around the sun and changes in the sun's activity contribute to ionospheric variations. There are two main classifications of these variations: regular variations that are predictable, and irregular variations resulting from abnormal behavior of the sun.

a. Regular Variations. The regular variations may be divided into four classes: the daily, or *diurnal*, caused by the rotation of the earth; the *seasonal*, caused by the north and south progression of the sun; the *27 day*, caused by the rotation of the sun on its axis; and the *11 year*, which is the average period during which sunspot activity varies from maximum to minimum and back to maximum.

b. Irregular Variations. The transient (momentary) ionospheric variations, though unpredictable, have important effects on radio propagation. Some of these effects are:

(1) *Sporadic E.* When it is excessively ionized, the E layer often completely blanks out the reflections from the higher layers. This effect may occur during the day or at night.

(2) *Sudden ionospheric disturbance.* A sudden ionospheric disturbance (SID) coincides with a bright solar eruption and causes abnormal ionization of the D layer. This effect causes total absorption of all frequencies above 1 MC. It occurs without warning during the day and may last from a few minutes to several hours. When SID occurs, receivers seem to go dead.

(3) *Ionosphere storms.* These storms may last from several hours to several days, and usually extend over the entire earth. During these storms, sky wave transmission above approximately 1.5 MC shows low intensity and is subject to a type of rapid blasting and fading called *flutter fading.*

39. Sky Wave Propagation

a. Sky Wave Transmission Paths. Sky wave propagation refers to those types of radio transmission that depend on the

ionosphere to provide signal paths between transmitters and receivers. Some of the possible paths radio waves can take from a transmitter to a receiver, using the ionosphere, are shown in figure 21.

b. Skip Zone. There is an area, called the skip zone, in which no usable signal can be received from a given transmitter operating at a given frequency. This area is bounded by the outer edge of usable ground-wave propagation and the point nearest the antenna at which the sky wave returns to earth—the *skip distance*. The skip zone and its relation to the ground wave are shown in figure 22. When the skip distance is within the range of the ground wave, there is no skip zone. In this case, both the sky wave and the ground wave may arrive at the antenna with nearly the same field intensity but a random relative phase. When this occurs, the sky-wave component alternately reinforces and cancels the ground-wave component, causing severe *blasting* (during reinforcement) and *fading* (during cancellation) of the signal. For each frequency (greater than the critical frequency) at which refraction from an ionosphere layer takes place, there is a skip distance that depends only on the frequency and the state of ionization. The skip zone, on the other hand, depends on the extent of the ground-wave range, and disappears completely if the ground-wave range exceeds the skip distance.

c. Sky Wave Paths. When a transmitted wave is refracted back to the surface of the earth, part of its energy is absorbed by the earth. The remainder of its energy is reflected back into the

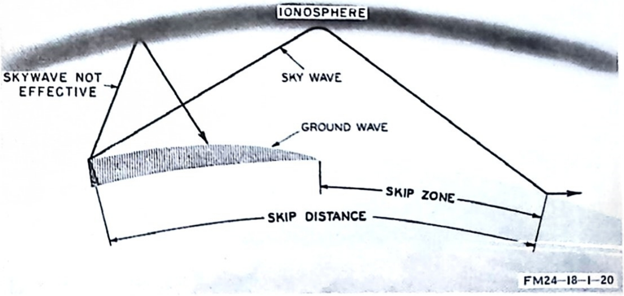

Figure 22. Skip zone.

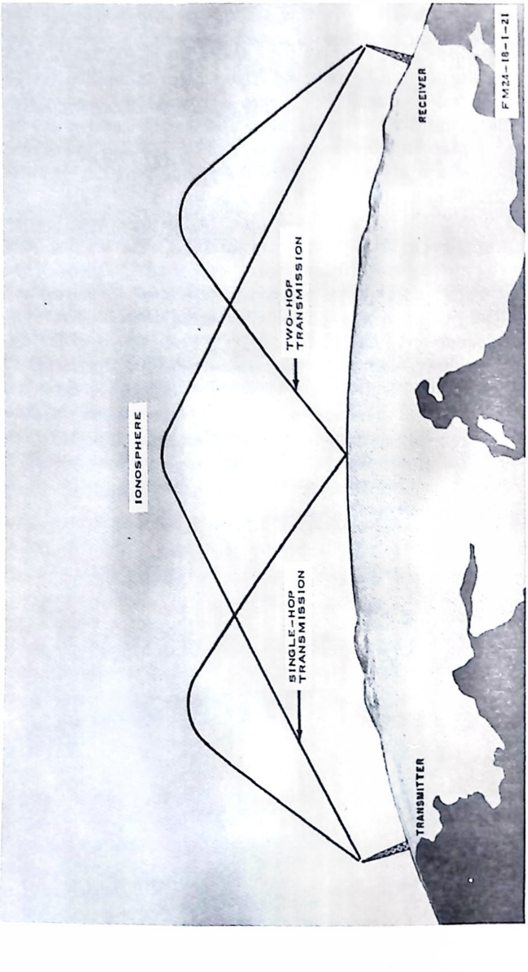

Figure 23. Sky-wave transmission paths.

ionosphere to be refracted again at a still greater distance from the transmitter. This means of travel in *hops* (fig. 23) by alternate refractions from the ionosphere and reflections from the earth may continue and enable radio waves to be received at great distances from the transmitter. Transmission is by a *single-hop path* when the radio wave reaches the receiving antenna after only one refraction from the ionosphere; and by a *double-hop* or *triple-hop path* when two or three refractions from the ionosphere are required.

40. Maximum Usable Frequency

a. Using a given ionized layer and a transmitting antenna with a fixed angle of radiation, there is a maximum frequency at which a wave will return to earth at a given distance. This frequency is called the *maximum usable frequency* (MUF), which is the monthly median of the daily highest frequency that is predicted for sky-wave transmission over a particular path at a particular hour of the day. It is always higher than the critical frequency, because the angle of incidence is less than 90 degrees. If the distance between the transmitter and the receiver is increased, the maximum usable frequency also will increase.

b. The maximum usable frequency usually is the most important factor to be considered when selecting the operating frequency for long-distance communication. If the operating frequency is above the MUF for a desired distance, communication is impossible and the wave will pass through the ionosphere into space or return to earth at a greater distance than is desired. Variations in the ion density of the ionosphere layers occur from day to day and from hour to hour. Predictions on which the MUF's are based are made by averaging long-range observations, and do not take into account these day-to-day fluctuations. Therefore, the actual upper-limiting frequency must be selected at a value which will insure against the probability of the operating frequency becoming greater than the MUF for any particular day. For the F2 layer, the optimum working frequency is selected at approximately 85 per cent of the MUF for that particular path. This new frequency is called the optimum traffic frequency (FOT) and has a predicted reliability of 90 per cent. The predicted reliability of the F2 MUF is 50 per cent. The FOT for the combined E-F layer may be taken as the path MUF, since the day-to-day variations in the E-layer ionization are small.

41. Lowest Useful Frequency

Radio waves lose some of their energy through absorption by the D region and the lower portion of the E region of the iono-

sphere at certain transmission frequencies. The total absorption is less and communication is more satisfactory as higher frequencies are used—up to the value of MUF. Absorption is at a maximum for frequencies ranging from approximately 500 KC to 2 MC during the day, but decreases at night at all frequencies. As the frequency for transmission over any given sky-wave path is increased, a value will be reached at which the received signal just overrides the level of atmospheric and other radio noises. This is called the *lowest useful frequency* (LUF), because frequencies lower than the LUF are too weak for useful communication. It should be noted, however, that the LUF depends on the power of the transmitter as well as on the transmission distance. When the value of LUF exceeds the value of MUF, no sky-wave transmission is possible at that frequency for that distance.

42. Fading

a. One common cause of fading is the result of interaction of two parts of the same radio wave (fig. 24). At a certain distance from the transmitter, both the ground wave and the sky wave may be received. Since these waves travel different paths, it is possible that they may arrive out of phase with each other. When this happens, the two waves tend to cancel each other at the meeting point.

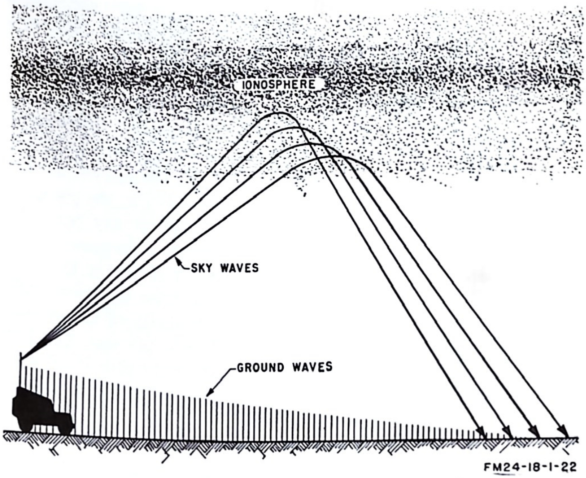

Figure 24. Fading caused by combination of ground and sky waves.

b. Another common cause of fading is the interaction of the components of a single sky wave. In this case, the various components will reach the receiver with varying phase differences, resulting in a continuously varying signal.

c. Violent changes in the ionosphere, known as *ionosphere storms,* may also cause severe fading, especially of frequencies higher than 1,500 KC. These disturbances are caused by vigorous sunspot activity and may last as long as several weeks.

d. The most common method of overcoming objectionable fading is to increase the power of the transmitter. The use of automatic gain control in the receiver will compensate for minor changes in signal intensity. Another method used to overcome fading is called *diversity reception.* In this case, two or more receiving antennas are spaced some distance apart, both feeding into the same receiver. Thus, if fading occurs in one antenna, the other may still receive a strong signal.

43. Effect of Frequency on Wave Propagation

a. At low frequencies (30 to 300 KC), the ground wave is extremely useful for communication over great distances. The ground-wave signals are quite stable and show little seasonal variation.

b. In the medium-frequency band (300 to 3000 KC), the range of the ground wave varies from about 15 miles (24 KM) at 3000 KC to about 400 miles (640 KM) at the lower frequencies of the band. Sky-wave reception is possible during day or night at any of the lower frequencies in this band. At night, the sky wave gives reception at distances up to 8,000 miles (12,870 KM).

c. In the high-frequency band (3 to 30 MC), the range of the ground wave decreases with an increase in frequency and the sky waves are greatly influenced by ionospheric considerations.

d. In the *very-high-frequency band* (30 to 300 MC), there is no usable ground wave and only slight refraction of sky waves by the ionosphere at the lower frequencies. The direct wave provides communication if the transmitting and receiving antennas are elevated sufficiently above the surface of the earth. Because of sporadic conditions in the ionosphere, transmission over any great range is unpredictable and is possible only for short periods of time.

e. In the *ultra-high-frequency band* (300 to 3000 MC), the direct wave must be used for all radio transmissions. Communication is limited to a short distance beyond the horizon. Lack of

static and fading in these bands makes line-of-sight reception very satisfactory. Highly directive antennas can be built into small spaces to concentrate RF energy into a narrow beam, thus increasing the signal intensity.

CHAPTER 5

ANTENNAS

Section I. INTRODUCTION

44. General

In a radio communication system (fig. 25), radio-frequency energy is generated by a radio transmitter and fed to a *transmitting antenna* by means of a transmission line. The antenna *radiates* this energy into space at approximately the speed of light. A *receiving antenna* absorbs part of this energy and sends it to the receiving equipment through another transmission line.

45. Functions of Antennas

The function of a transmitting antenna is to convert the output power delivered by a radio transmitter into an electromagnetic field that is radiated through space. As such, the transmitting antenna converts energy having one form to energy having another form. The receiving antenna makes the energy conversion in the opposite direction. The function of the receiving antenna is to convert the electromagnetic field that sweeps by it into energy that is delivered to a radio receiver. In transmission, the antenna operates as the load for the transmitter; in reception, it operates as the signal source for the receiver.

46. Antenna Gain

The gain of an antenna depends primarily on its design. Transmitting antennas are designed for high efficiency in radiating energy, and receiving antennas are designed for the efficient pickup of energy. On some radio circuits, transmission is required between a transmitter and only one receiving station. In such cases, it is desirable to radiate as much energy as possible in one direction, since radiated energy is useful only in that direction. Directional characteristics in a receiving antenna increase the energy pickup or gain in the favored direction and reduce the reception of unwanted noise and signals from other directions. The general requirements for transmitting and receiving antennas are that they have small energy losses and that they be efficient as radiators and receptors.

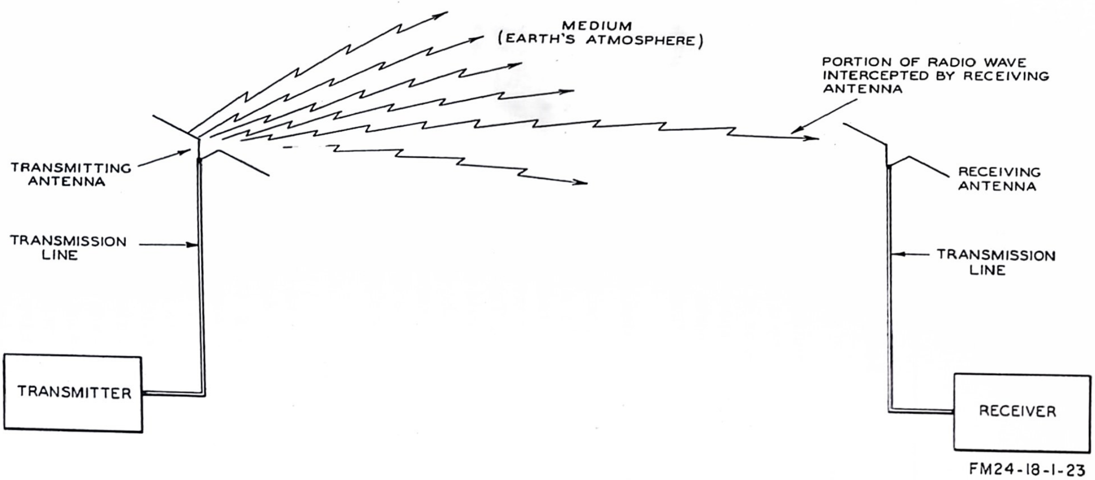

Figure 25. Simple radio communications network.

47. Radiation

a. When power is delivered to an antenna, two fields are set up by the fluctuating energy: one is the induction field, which is associated with the stored energy; the other is the radiation field, which moves out into space at nearly the speed of light. At the antenna, the intensities of these fields are high and are proportional to the amount of power delivered to the antenna. At a short distance from the antenna, and beyond, only the radiation field remains. This radiation field is composed of an electric component and a magnetic component.

b. The electric and magnetic fields (components) radiated from an antenna form the electromagnetic field, and this field is responsible for the transmission and reception of electromagnetic energy through free space. Thus, the radio wave may be described as a moving electromagnetic field, having velocity in the direction of travel, and with components of electric intensity and magnetic intensity arranged at right angles to each other (fig. 26).

48. Antenna Radiation Patterns

a. The energy of radio signals radiated by an antenna forms an electromagnetic field having a definite pattern, depending on the type of antenna used. This radiation pattern is used to show both range and directional characteristics of an antenna. A vertical antenna theoretically radiates energy equally in all directions. In practice, however, the pattern is usually distorted by nearby obstructions or terrain features.

b. The full- or solid-radiation pattern is a 3-dimensional figure that looks somewhat like a doughnut, with a transmitting antenna

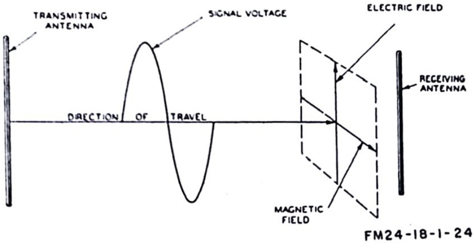

Figure 26. Components of electromagnetic waves.

in the center (fig. 27). The top pattern in the figure is that of a quarter-wave vertical antenna; the bottom pattern is that of a half-wave horizontal antenna, ½-wavelength above the ground. The general method of illustrating a radiation pattern, however, is by cross section of the full pattern, showing only one particular plane (fig. 28). The top pattern of the figure is that of a half-wave horizontal antenna, ¼-wavelength above the ground; the bottom pattern is that of a half-wave horizontal antenna, ½-wavelength above the ground.

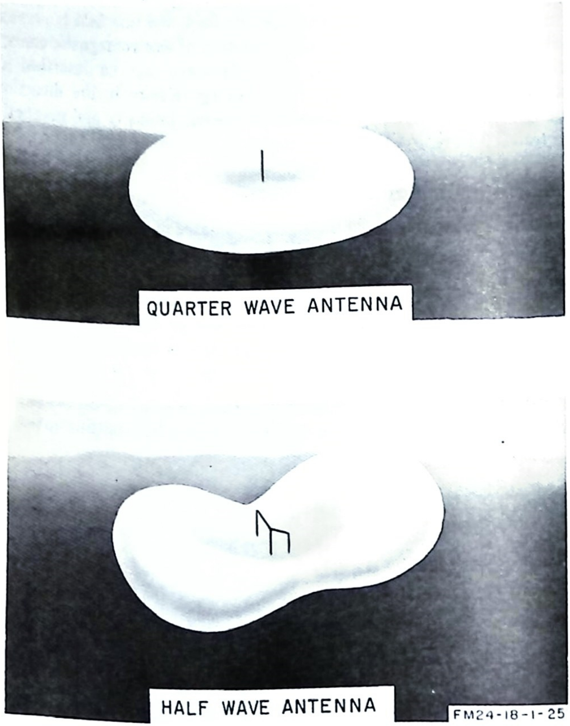

Figure 27. Solid radiation patterns from quarter-wave and half-wave antennas.

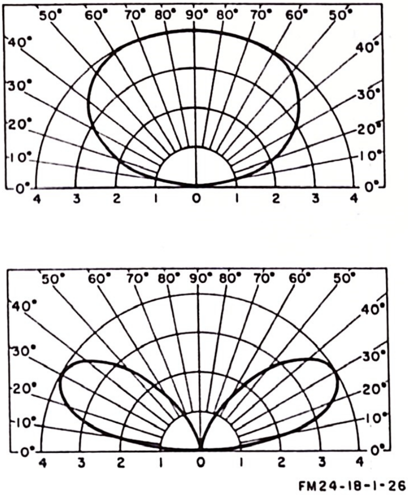

Figure 28. Cross-sectional representation of radiation pattern in one plane.

49. Polarization

a. Polarization of a radiated wave is determined by the direction of the lines of force making up the electric field. If the lines of electric force are at right angles to the surface of the earth, the wave is said to be vertically polarized (fig. 29). If the lines of electric force are parallel to the surface of the earth, the wave is said to be horizontally polarized (fig. 30).

b. When a single-wire antenna is used to extract energy from a passing radio wave, maximum pickup results if the antenna is so oriented that it lies in the same direction as the electric-field component. Thus, a vertical antenna is used for efficient reception of vertically polarized waves and a horizontal antenna is used for the reception of horizontally polarized waves. In some cases, the field rotates as the waves travels through space. Under these conditions, both horizontal and vertical components of the field exist and the wave is said to have elliptical polarization.

50. Polarization Requirements for Various Frequencies

a. At medium and low frequencies, ground-wave transmission is used extensively and it is necessary to use vertical polarization.

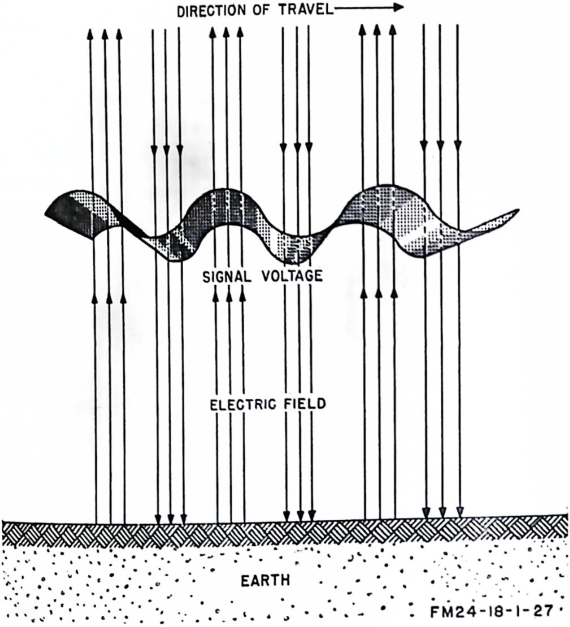

Figure 29. Vertically polarized signal.

Vertical lines of force are perpendicular to the ground, and the radio wave can travel a considerable distance along the ground surface with a minimum amount of attenuation (loss). Because the earth acts as a fairly good conductor at low frequencies, horizontal lines of electric force are shorted out and the useful range with horizontal polarization is limited.

b. At high frequencies, with sky-wave transmission, it makes little difference whether horizontal or vertical polarization is used. The sky wave, after being reflected by the ionosphere, arrives at the receiving antenna elliptically polarized. Therefore, the transmitting and receiving antennas can be mounted either horizontally or vertically. Horizontal antennas are preferred, however, since they can be made to radiate effectively at high angles and have inherent directional properties.

c. With frequencies in the very-high or ultra-high range, either horizontal or vertical polarization is satisfactory. Since the radio

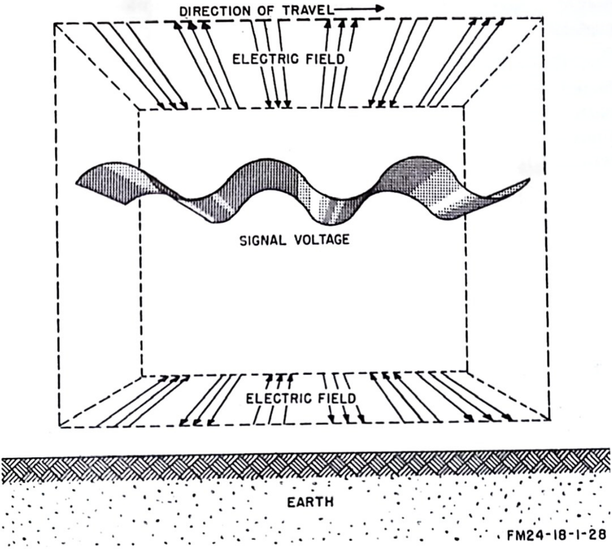

Figure 30. Horizontally polarized signal.

wave travels directly from the transmitting antenna to the receiving antenna, the original polarization produced at the transmitting antenna is maintained throughout the travel of the wave to the receiving antenna. Therefore, if a horizontal half-wave antenna is used for transmitting, a horizontal antenna must be used for receiving. If a vertical half-wave antenna is used for transmitting, a vertical antenna must be used for receiving.

51. Advantages of Vertical Polarization

a. Simple, vertical, half-wave antennas can be used to provide omnidirectional (in all directions) communication. This is advantageous when it is desired to communicate with a moving vehicle.

b. When antenna heights are limited to 10 feet or less over land, as in a vehicular installation, vertical polarization provides a stronger received signal at frequencies up to about 50 MC. From approximately 50 to 100 MC there is only a slight improvement over horizontal polarization with antennas at the same

height. Above 100 MC the difference in signal strength is negligible.

c. Radiation using vertical polarization is somewhat less affected by reflections from aircraft flying over the transmission path. With horizontal polarization, such reflections cause variations in received signal strength. This factor is important in areas where aircraft traffic is heavy.

d. When vertical polarization is used, less interference is produced or picked up because of strong VHF and UHF broadcast transmission and reception (television and frequency modulation), all of which use horizontal polarization. This factor is important when an antenna must be located in an urban area that has television or FM broadcast stations.

52. Advantages of Horizontal Polarization

a. A simple horizontal half-wave antenna is bidirectional. This characteristic is useful if it is desired to minimize interference from certain directions.

b. Horizontal antennas are less apt to pick up man-made interference, which ordinarily is polarized vertically.

c. When antennas are located near dense forests, horizontally polarized waves suffer lower losses than vertically polarized waves, especially above about 100 MC.

d. Small changes in antenna location do not cause large variations in the field intensity of horizontally polarized waves when antennas are located among trees or buildings. When vertical polarization is used, a change of only a few feet in the antenna location may have a considerable effect on the received signal strength.

e. When simple half-wave antennas are used, the transmission line, usually vertical, is less affected by a horizontally mounted antenna. By keeping the antenna at right angles to the transmission line and using horizontal polarization, the line is kept out of the direct field of the antenna. As a result, the radiation pattern and electrical characteristics of the antenna are practically unaffected by the presence of the vertical transmission line.

53. Receiving Antennas

a. Vertical receiving antennas accept radio signals equally from all horizontal directions, just as vertical transmitting antennas radiate equally in all horizontal directions. Because of this

characteristic, other stations operating on the same or adjacent frequencies may interfere with the desired signal and make reception difficult or impossible. However, reception of a desired signal can be improved by using directional antennas.

b. Horizontal half-wave antennas accept radio signals from all directions other than the two directions in direct line with the ends of the antenna. Thus, when only one signal is causing interference, or when several interfering signals are coming from the same direction, interference can be eliminated or reduced by changing the antenna installation so that either end of the antenna points directly at the interfering station.

54. Directivity

Communication over a radio circuit is satisfactory when the received signal is strong enough to override undesired signals and noise. In other words, the receiver must be within range of the transmitter. Communication effectiveness can be increased between two radio stations by increasing the transmitting power, changing the type of emission (for example, changing from radiotelephone to CW), changing to a frequency that is not readily absorbed, or using a more directional antenna. In point-to-point communication, it is usually more economical to increase the directivity of the antenna system. Directional transmitting antennas concentrate radiation in a given direction and minimize radiation in other directions. A directional antenna may also be used to lessen interception by the enemy and interference with friendly stations.

Section II. ANTENNA PERFORMANCE

55. General

a. Since all practical antennas are erected over the earth and not out in free space, the presence of the ground may alter completely the free space radiation pattern of the antenna, and the ground will also have an effect on some of the electrical characteristics of the antenna.

b. In general, the ground has the greatest effect on those antennas that must be mounted fairly close to it in terms of wavelength. For example, medium- and high-frequency antennas elevated above the ground by only a fraction of a wavelength will have radiation patterns that are quite different from the free-space patterns.

56. Grounded Antenna

a. The ground is a fairly good conductor for medium and low frequencies and acts as a large mirror for the radiated energy. This results in the ground reflecting a large amount of energy that is radiated downward from an antenna mounted over it.

b. Utilizing this characteristic of the ground, an antenna only a quarter-wavelength long can be made into the equivalent of a half-wave antenna. If such an antenna is erected vertically and its lower end is connected electrically to the ground (fig. 31), the quarter-wave antenna behaves like a half-wave antenna. Under these conditions, the ground takes the place of the missing quarter-wavelength, and the reflections supply that part of the radiated energy that normally would be supplied by the lower half of an ungrounded half-wave antenna.

57. Types of Grounds

a. When grounded antennas are used, it is especially important that the ground have as high a conductivity as possible. This will reduce ground losses and provide the best possible reflecting surface for the down-going radiated energy from the antenna. At low and medium frequencies, the ground acts as a sufficiently

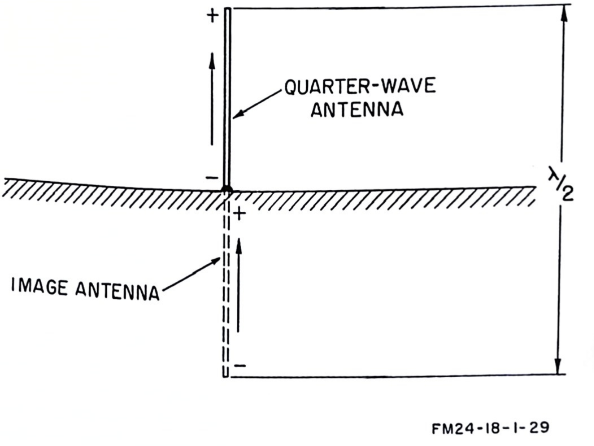

Figure 31. Quarter-wave antenna connected to ground.

good conductor and the ground connection must be made in such a way as to introduce the least possible amount of resistance in the ground connection. At higher frequencies, artificial grounds constructed of large metal surfaces are common.

b. The ground connection takes many forms, depending on the type of installation and the loss that can be tolerated. In many simple field installations, the ground connection is made by means of one or more metal rods driven into the earth. Where more satisfactory arrangements cannot be made, it may be possible to make ground connections to existing devices which are themselves grounded. Metal structures or underground pipe systems commonly are used as ground connections. In an emergency, a ground connection can be made by plunging one or more bayonets into the earth.

c. When an antenna must be erected over soil having a very low conductivity, it is advisable to treat the soil directly to reduce its resistance. The soil may be mixed with a quantity of coal dust for this purpose; it can also be treated with substances that are highly conductive when in solution. Some of these substances, listed in order of preference, are sodium chloride (common salt), calcium chloride, copper sulphate (blue vitriol), magnesium sulphate (Epsom salt) and potassium nitrate (saltpeter). The amount required depends on the type of soil and its moisture content.

***Warning:* When these substances are used, it is important that they do not get into nearby drinking water supplies.**

d. For simple installations, a single ground rod can be fabricated in the field from pipe or conduit. It is important that a low resistance connection be made between the ground wire and the ground rod. The rod should be cleaned thoroughly by scraping and sandpapering at the point where the connection is to be made, and a clean ground clamp should be installed. A ground wire can then be soldered or joined to the clamp. This joint should be covered with tape to prevent an increase in resistance because of oxidation.

58. Counterpoise

a. When an actual ground connection cannot be used because of the high resistance of the soil or because a large buried ground system is not practicable, a counterpoise may replace the usual direct ground connection in which current actually flows to and from the antenna through the ground itself. The counterpoise (fig. 32) consists of a structure made of wire, which is erected

a short distance off the ground and insulated from the ground. The size of the counterpoise should be at least equal to the preferably larger than the size of the antenna.

b. When the antenna is mounted vertically, the counterpoise should be made into a simple geometric pattern such as those shown in figure 32. Perfect symmetry is not required, but the counterpoise should extend for equal distances in all directions from the antenna.

c. In some VHF antenna installations on vehicles, the metal roof of the vehicle is used as a counterpoise for the antenna.

d. Small counterpoises of metal mesh are sometimes used with special VHF antennas that must be located a considerable distance above the ground. This counterpoise provides an artificial ground that helps to produce the required radiation pattern.

59. Ground Screen

a. A ground screen consists of a fairly large area of metal mesh or screen that is laid on the surface of the ground under the

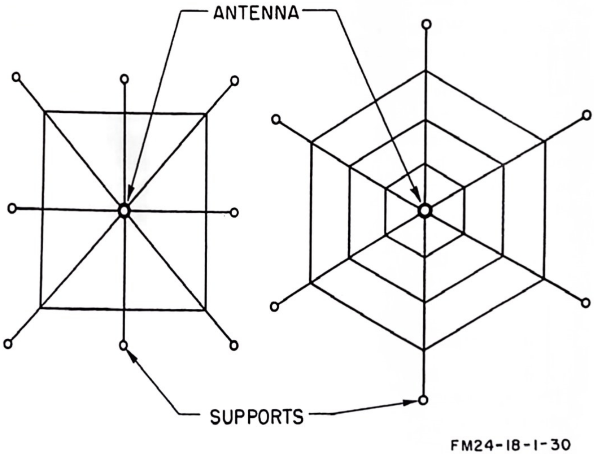

Figure 32. Wire counterpoises.

antenna. Its purpose is to simulate to some extent the effect of a perfect conducting ground under the antenna.

b. There are two specific advantages that can be gained through use of a ground screen. First, the ground screen reduces ground absorption losses that occur when an antenna is erected over imperfectly conducting ground. And second, the height of the antenna can be set accurately. As a result of this, the radiation resistance of the antenna can be determined and the radiation patterns of the antenna can be predicted more accurately (TM 11–666).

Section III. TYPES OF ANTENNAS

60. General

a. There are many shapes and sizes of antennas used for radio transmission, and several different electrical types of antennas. Some of the factors that determine the type, size, and shape of the transmitting antenna to be used are the—

(1) Operating frequency of the transmitter.

(2) Amount of power to be radiated.

(3) General direction of the distant receiving set.

(4) Polarization desired.

(5) Use for which the antenna is required.

b. Several types of transmitting antennas are shown in figure 33.

(1) A is a long-wire nonresonant antenna that is used in large fixed-station installations.

(2) B is a half-wave Hertz antenna that is fed by a resonant (tuned) feeder line from the transmitter.

(3) C is an end-fed, vertical, modified Marconi antenna, also called a whip antenna.

(4) D is a loop antenna that radiates a strong signal in some directions and almost no signal in other directions.

(5) E is a Marconi antenna.

(6) F is a half-wave Hertz antenna that is fed by a nonresonant (untuned) feeder line from the transmitter.

(7) G is a fixed-station radiator that may be hundreds of feet high.

c. Most practical transmitting antennas come under one of two classifications, *Hertz antennas* or *Marconi antennas*. A Hertz antenna is operated some distance above the ground, and may be

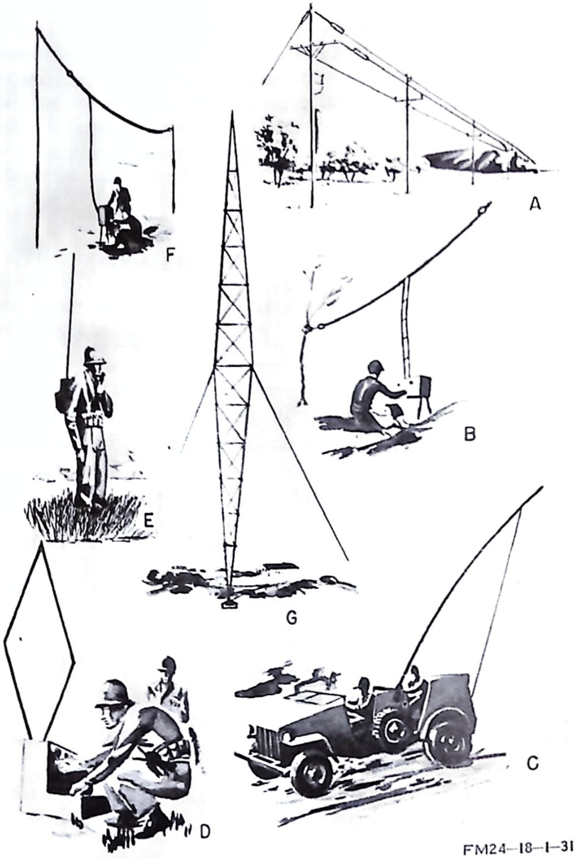

Figure 33. Types of transmitting antennas.

either vertical or horizontal. A Marconi antenna operates with one end grounded (usually through the output of the transmitter or the coupling coil at the end of the feed line). Hertz antennas are generally used at higher frequencies (above about 2 MC),

while Marconi antennas are generally used at lower frequencies. Marconi antennas, when used on vehicles or aircraft, operate at high frequencies; in these cases, the aircraft or vehicle chassis becomes the effective ground for the antenna.

61. Hertz Antenna

a. The operation of the Hertz antenna is based on the fact that the wavelength to which any wire will tune depends directly upon its length. The radiator is thus self-tuned and no ground or other conducting plane is necessary. Consequently, the Hertz antenna can be placed where it is less disturbed by the effects of grounded objects, such as buildings and shrubbery.

b. The basic Hertz antenna is a single wire with a length equal to approximately one-half of the wavelength of the signal to be transmitted. This type of antenna, which is also known as a doublet, dipole, ungrounded, or half-wave antenna, can be mounted in a vertical, horizontal, or slanting position.

c. Two typical military half-wave center-fed Hertz antennas are shown in figures 34 and 35. These antennas are used for the transmission and reception of radio signals between 1.5 and 18 MC.

62. Marconi Antenna

a. If the lower half of a vertical Hertz antenna is replaced by an extensive conducting plane, no disturbance is caused in the propagated waves from the upper half. In other words, the remaining quarter-wave will continue to radiate much in the same

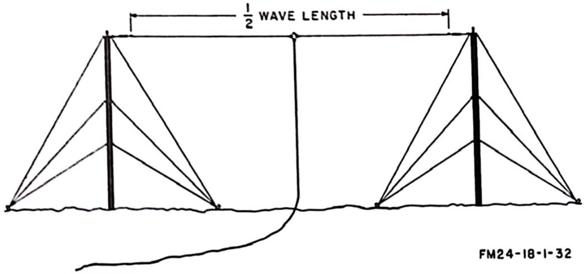

Figure 34. Center-fed Hertz antenna with two upright supports.

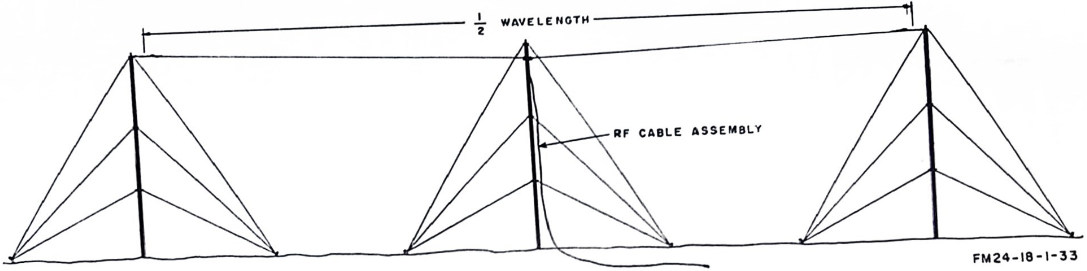

Figure 35. Center-fed Hertz antenna with three upright supports.

way as a half-wave antenna, provided a large and extensive conducting plane is present. A practical form of such a radiating system is the Marconi antenna, in which the antenna proper provides one quarter-wavelength, and the earth supplies the additional quarter-wavelength. The total effective (or electrical) length is then one half-wavelength.

b. Establishment of the conducting plane is not always easily accomplished, since the earth in many localities is dry and sandy. When this is the case, a counterpoise is used.

c. The main advantage of the Marconi antenna lies in the fact that, for any given frequency, it is much shorter than the Hertz antenna. This is of particular importance in all field and vehicular radio installations. Typical Marconi antennas are the inverted-L, the whip, the ground-plane, and the modified ground-plane antennas.

63. Inverted-L Antenna

a. An inverted-L antenna is a grounded antenna so constructed that a portion of it is mounted horizontally. The horizontal portion, or flattop, is fairly long, and the vertical downlead, which forms an important part of the radiating system, is connected to one end of the flattop. The length of the antenna is measured from the far end of the flattop to the point at which the downlead is connected to the transmitter.

b. For ground-wave propagation, the vertical part radiates most of the ground wave and the horizontal part is used for top loading. For short-distance sky-wave propagation, the horizontal part radiates most effectively and the vertical portion merely functions as a lead-in. For medium-distance sky-wave propagation, both parts contribute to the radiation.

c. The purpose of the inverted-L antenna is to afford satisfactory operation when it is not convenient to erect tall vertical antennas. This is particularly necessary when operation on the lower freqencies is required.

d. The inverted-L antenna shown in figure 36 is a common military-type antenna. It consists of a single-wire antenna and a signal-wire counter-poise. It may be used as either a half-wave antenna (4 to 8 MC) or a quarter-wave antenna (2 to 4 MC).

64. Ground-Plane Antenna

a. One type of ground-plane antenna (fig. 37) is a quarter-wave vertical radiator that in effect, carries its own artificial

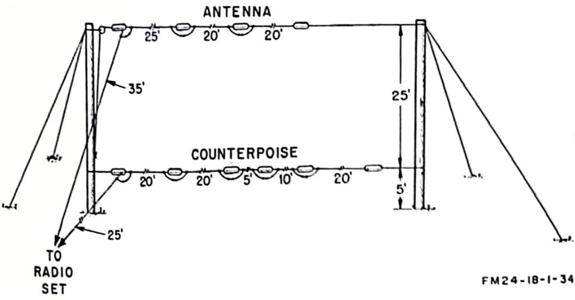

Figure 36. Inverted-L military antenna.

ground. The artificial ground, or ground plane, consists of three ground-plane elements that make an angle of 142° with the vertical element. These elements may be called a counter-poise, but they are generally known as an *elevated ground plane*.

b. The ground-plane antenna is used when non-directional horizontal radiation or reception is required. It is particularly useful in extending the distance range of field radio sets operating from 20 to 70 MC. This antenna should be well elevated to minimize ground losses.

65. Whip Antennas

a. Whip antennas (fig. 38) are the most commonly used antennas for tactical radio communication over relatively short distances. The term whip antenna is applied to almost any type of flexible radiator used in conjunction with portable or mobiie radio equipment.

b. Most whip antennas are constructed of sections of metal tubing that can be taken apart when not in use. In this way, the antenna has a minimum length during transit and portability is increased. In some lightweight portable equipment, the antenna can be collapsed completely into the equipment itself so that none of it is exposed.

c. There are times when a whip antenna mounted on a vehicle must be left fully extended so that it can be used instantly while the vehicle is in motion. In such antennas, the base mounting insulator of the whip is fitted with a coil spring attached to a

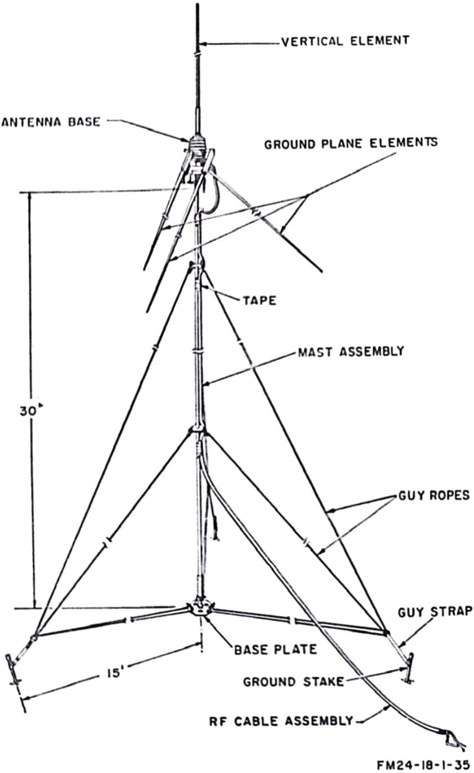

Figure 37. Ground-plane antenna.

mounting bracket on the vehicle. The spring base holds the whip antenna in a horizontal position so that the vehicle can be driven under low bridges or obstructions. If the antenna hits an obstruction, the whip usually will not break because most of the shock will be absorbed by the spring base.

WARNING: **When an antenna must be left fully extended while in motion, contact with overhead power lines must be avoided.**

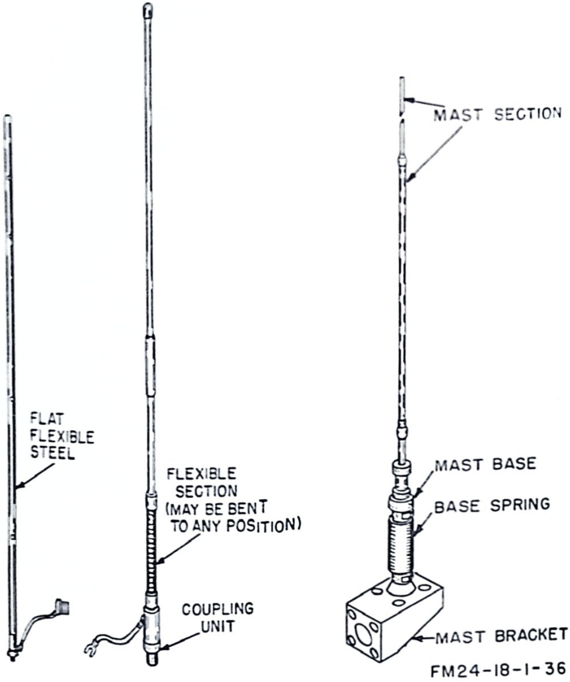

Figure 38. Common types of whip antenna.

Death or serious injury can result if a vehicular antenna strikes a high-voltage transmission line.

d. When a whip antenna is mounted on a vehicle, the metal of the vehicle will affect the operation of the antenna. As a result, the direction in which the vehicle is facing may also affect transmission and reception, particularly of distant or weak signals.

e. A vehicle with a whip antenna mounted on its left rear side will transmit its strongest signal in a line running from the antenna through the right front side of the vehicle (A, fig. 39).

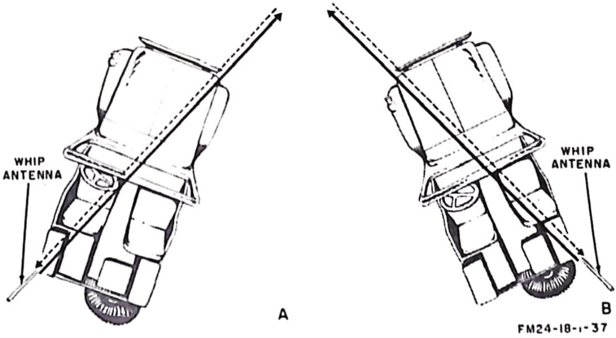

Figure 39. Best directivity of whip antenna mounted on vehicle.

Similarly, an antenna mounted on the right rear side of the vehicle radiates its strongest signal in a direction toward the left front side (B, fig. 39). The best reception is obtained from signals traveling in the directions shown by the broken arrows.

f. In some cases, the best direction can be determined by driving the vehicle in a small circle until the best position is located. Normally, the best direction for receiving from a distant station is also the best direction for transmitting to that station.

66. Dummy Antennas

Use of a radiating antenna may divulge the location of a transmitter to enemy radio direction finders and may also cause interference with other stations operating on the same frequency. To eliminate the possibility of unauthorized signals going on the air, a dummy antenna is sometimes provided. This device will act as a load for the transmitter without radiating a signal. Dummy antennas normally consist of a non-inductive resistor large enough to absorb the transmitter output and dissipate it as heat. Some dummy antennas also have an RF wattmeter to check the transmitter RF power output.

Section IV. FIELD EXPEDIENTS FOR ANTENNAS

67. Improvised or Emergency Antennas

Antennas are sometimes broken or damaged, thereby causing communication failure or poor communication. If a spare is avail-

able, the damaged antenna can be replaced. When there is no spare, it may be necessary to fabricate an emergency antenna. The following are suggestions that will aid in the construction of an emergency antenna.

a. General Suggestions.

(1) The best types of wire for antennas are copper or aluminum. In an emergency, however, use any type that is available.

(2) The exact length of many antennas is critical. Therefore, the length of the emergency antenna should be the same as the length of the antenna it replaces.

(3) Antennas supported by trees can usually survive heavy wind storms if the trunk of a tree or a stout branch is used as the supporting limb. To keep the antenna taut and to prevent it from breaking or stretching as the trees sway, attach a spring or old inner tube to one end of the antenna, or pass a rope through a pulley or eyehook, attach the rope to the end of the antenna, and load the rope with a heavy weight to keep the antenna taut.

(4) Guys used to hold antenna supports are made of rope or wire. To insure that wire guys will not affect the operation of the antenna, cut the wire into several short lengths and connect the pieces with insulators.

b. Antenna Efficiency. An improvised antenna may change the performance of a radio set. Two expedient methods may be used to determine whether the improvised antenna is operating properly.

(1) The distant receiver may be used to test the antenna. If the signal received from a station is strong, the antenna is operating satisfactorily. If the signal is weak, adjust the height and length of the antenna and transmission line to receive the strongest signal at a given setting of the volume control of the receiver.

(2) In some radio sets, the transmitter is used to adjust the antenna. First, set the controls of the transmitter in the proper position for normal operation; then, tune the system by adjusting the antenna height, the antenna length, and the transmission line length to obtain the best transmission output.

***WARNING:* Serious injury or death can result from contact with the radiating antenna of a medium or high power transmitter. Turn the transmitter off while making adjustments to the antenna.**

68. Repair of Whip Antennas

When a whip antenna is broken into two sections, the portion of the antenna that is broken off can be connected to the portion attached to the base fitting by joining the sections as shown in figure 40. Use the method illustrated in figure 40A when both parts of the broken whip are available and usable. Use the method illustrated in figure 40B when the portion of the whip that was broken off is lost or when the whip is so badly damaged that it is unfit for use. To restore the antenna to its original length, add a piece of wire that is nearly the same length as the missing part of the whip. Then, lash the pole support securely to both sections of the antenna. Clean the two antenna sections thor-

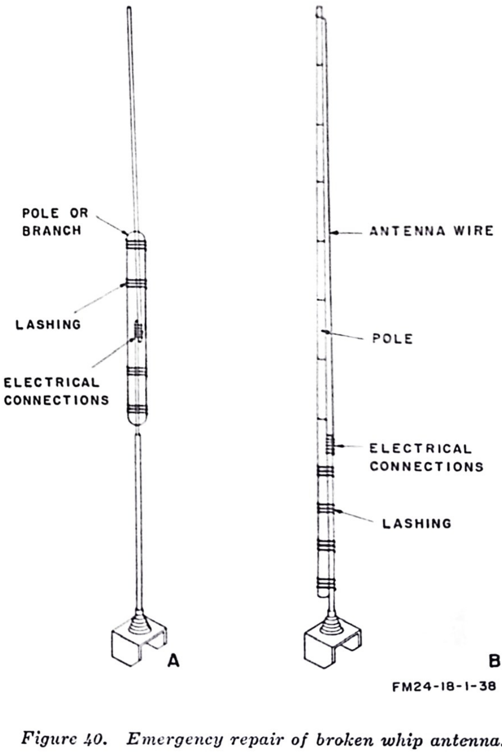

Figure 40. Emergency repair of broken whip antenna.

oughly to insure good contact before connecting them to the pole support. If possible, solder the connections.

69. Repair of Wire Antennas

Emergency repair of wire antennas can be grouped into two categories: repair or replacement of the wire used as an antenna or transmission line; and repair or replacement of the assembly used to support the antenna wires.

a. When one or more wires on an antenna are broken, the antenna can be repaired by reconnecting the broken wires. To do this, lower the antenna to the ground, clean the surface of the wire, and twist the wires together. Whenever possible, solder the connection.

b. If the antenna is damaged beyond repair, substitute another antenna. Make sure that the length of the substitute antenna is approximately the same as that of the original antenna.

70. Repair of Antenna Supports

Antenna supports may require repair or replacement in the same manner as the antenna. A substitute item may be used in place of a damaged support and can be of any material of adequate strength if properly insulated.

a. Insulators. Normally, an antenna is suspended between two support lines, which are attached to poles, trees, or buildings. The support lines, usually pieces of wire or rope, are electrically separated from the antenna by means of glass or porcelain insu-

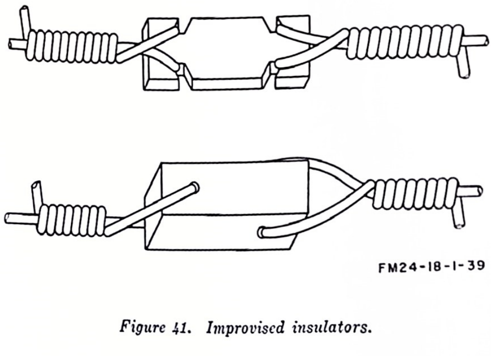

Figure 41. Improvised insulators.

lators. If an insulator breaks and a spare insulator is not available, the antenna can be effectively insulated by inserting a piece of dry wood between the antenna wire and the line support. Figure 41 shows two methods of making emergency wooden insulators. If rope is used for the antenna supporting line, the rope, if dry, may be connected directly to the antenna wire. If the rope contains a metal wire to provide mechanical strength, an insulator must be used.

Note. Wood or dry rope should be used as insulators only in emergencies when better insulators cannot be obtained or improvised.

b. Guys. Lines used to stabilize the supports for an antenna are called *guys.* These lines are usually made of wire, manila rope, or nylon rope. If a rope breaks, it may be repaired by tying the two broken ends. If the rope is too short after the tie is made, it can be lengthened by adding another piece of rope or any other insulating material, such as a piece of dry wood or cloth. If a wire guy breaks, it can be replaced with another piece of wire.

c. Masts. Some antennas are supported by masts. Thus, if a mast breaks, it can be replaced with another of the same length. If long poles are not available as replacements, short poles may be overlapped and lashed together with rope or wire to provide a pole of the required length.

71. Vertical Antennas

A vertical antenna is properly adjusted if the antenna electrical length is the same as the electrical length of the antenna normally supplied with the radio set. If this length is unknown, it is necessary to construct a long antenna and adjust the electrical length by trimming off the end until the best electrical length is obtained. This same trimming process can be used for vertical wire antennas, but is not practical for metal-rod or pipe antennas.

a. A vertical antenna can be improvised by using a metal pipe, or rod of the correct length, held erect by means of guys. The lower end of the antenna should be insulated from the ground by placing it on a large block of wood or other insulating material.

b. A vertical antenna may consist of wire supported by a tree or a wooden pole (A, fig. 42). For short vertical antennas, the pole may be used without guys (if properly supported at the base). If the length of the vertical mast is not long enough to support the wire upright, it may be necessary to modify the connection at the top of the antenna (B, fig. 42).

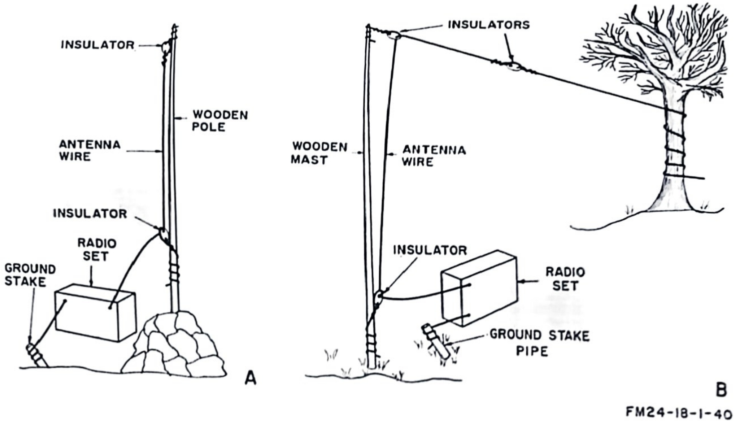

Figure 42. Field substitutes for vertical wire antennas.

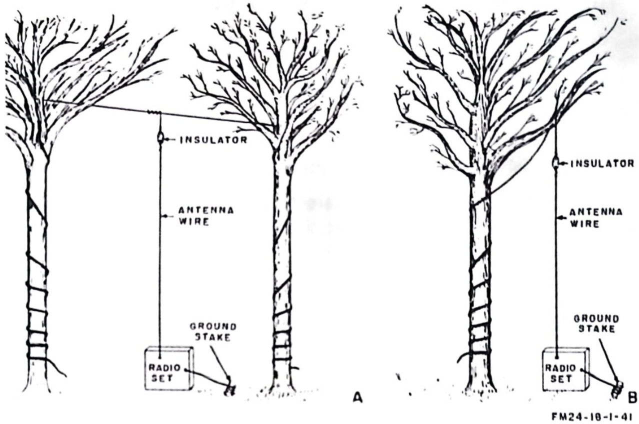

Figure 43. Additional means of supporting vertical wire antennas.

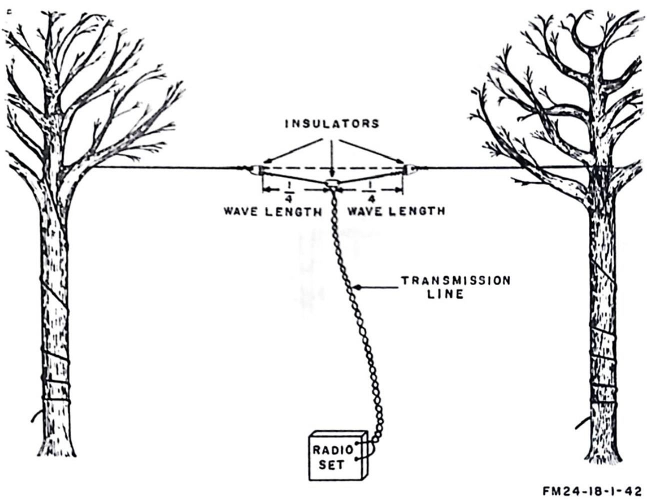

Figure 44. Improvised center-fed half-wave antenna.

c. Another method of supporting a vertical wire antenna is shown in A, figure 43. A line is strung between two trees at the desired height to support the antenna wire.

d. A vertical antenna can also be suspended from the branch of a tree (B, fig. 43). In this case, the antenna must be free from contact with other branches. It may be supported by rope or similar material.

72. Center-Fed Half-Wave Antenna

An emergency antenna of this type can be made of wire and rope (fig. 44). An insulator is placed at the exact center of the antenna, and a double-wire feeder or transmission line is connected at the insulator. One wire of the transmission line is connected to one side of the antenna, and the second wire is connected to the other side of the antenna. The unattached ends of the transmission lines are then connected to the two antenna terminals of the radio set.

a. The length of the antenna wires is important. Cut the wires as closely as possible to the correct length.

b. The length of the transmission line is also important, and the transmission lines should be adjusted to obtain the best results. To accomplish this, install transmission lines that are longer than necessary and then shorten them to obtain the best opera-

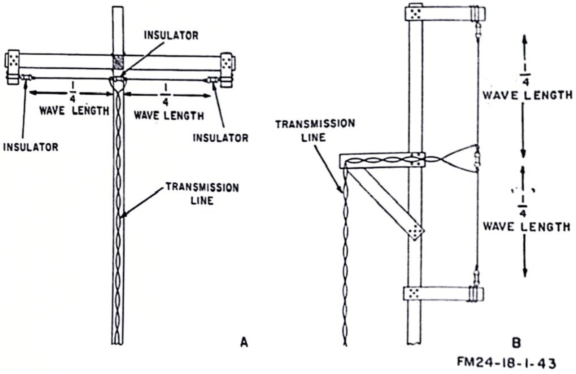

Figure 45. Elevated center-fed half-wave antenna.

tion. If a coaxial cable transmission line is used, trimming is not practical.

c. If an open-wire line is used, performance can be improved by connecting a piece of wire between the ends of the antenna (folded dipole), as indicated by the dotted line in figure 44. This piece of wire should be the same length as the actual antenna.

d. A general formula for finding the physical length of a half-wave antenna and a chart of half-wave antenna lengths for frequencies from 1 MC to 76 MC are contained in appendix II.

e. Short center-fed half-wave antennas can be supported entirely by pieces of wood. A horizontal antenna of this type is

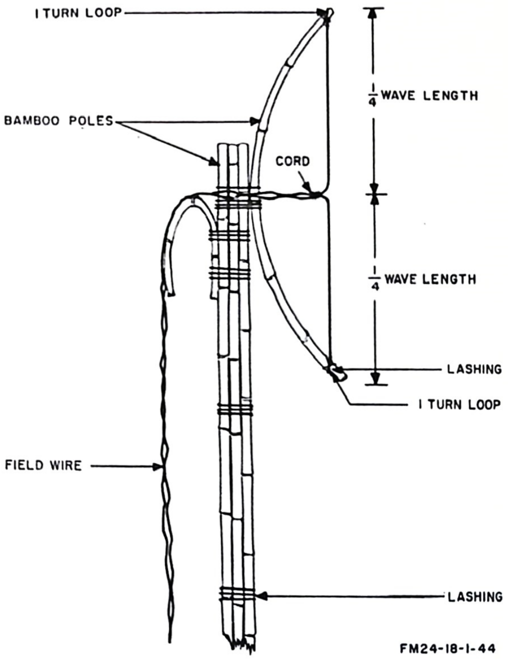

Figure 46. Means of supporting vertical half-wave antenna.

shown in A, figure 45; a vertical antenna of similar type is shown in B, figure 45. These antennas can be rotated to any position to obtain the best performance. If the antenna is erected vertically, the transmission line should be brought out horizontally from the antenna for a distance equal to at least one-half of the antenna's length before it is dropped down to the radio set.

f. A similar arrangement for a short, center-fed half-wave antenna is shown in figure 46. The ends of this antenna are connected to a piece of dry wood, such as a bamboo pole, and the bend in the pole holds the antenna wire straight. Another pole, or bundle of poles, serves as a mast.

73. End-Fed Half-Wave Antenna

An emergency antenna of this type can be fabricated if materials such as field wire, rope, and wooden insulators are available. The electrical length of this antenna is measured from the antenna terminal on the radio set to the far end of the antenna (B, fig. 42). The best performance can be obtained by construct-

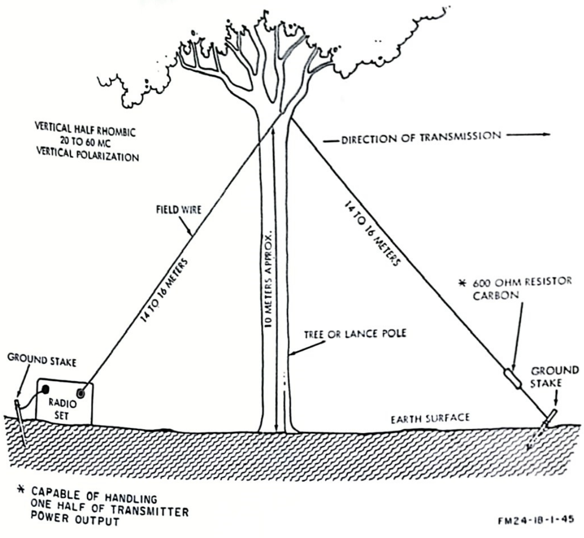

Figure 47. Half-rhombic antenna.

ing the antenna longer than necessary, and then shortening it until performance is satisfactory.

74. Field Expedient Directional Antennas

The vertical half-rhombic antenna (fig. 47) and the wave antenna (fig. 48) are the two field-expedient directional antennas that can be used with the FM radio sets. These antennas are directional and will transmit and receive in the direction of the terminated end. If the transmitter loads poorly, add to or subtract from the length of the antenna. These antennas will normally increase the rated operating range of the FM sets.

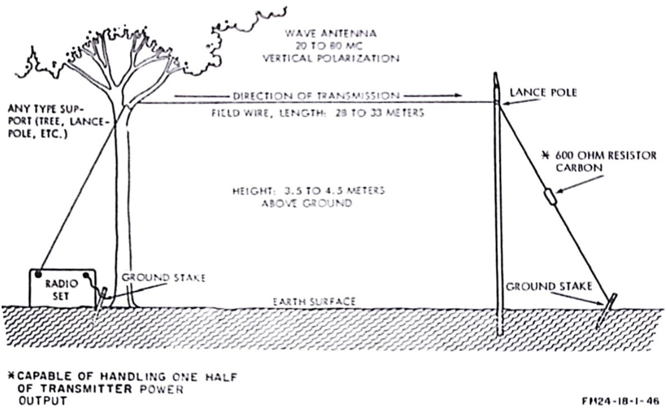

Figure 48. Wave antenna.

CHAPTER 6

FACTORS CONTROLLING RELIABILITY OF RADIO COMMUNICATIONS

Section I. SELECTION OF SITE

75. Technical Requirements

a. Location. A radio station must be located in a position that will assure communication with all other stations with which it is to operate. To obtain efficiency of transmission and reception, the following factors should be considered:

(1) Hills and mountains between stations normally limit the range of radio sets. In mountainous or hilly terrain, positions relatively high on the slopes (fig. 49) should be selected. Locations at the base of a cliff or in a deep ravine or valley (fig. 50) should be avoided. For operation at frequencies above 30 MC, a location that will give line-of-sight communication should be selected whenever possible.

(2) Dry ground has high resistance and limits the range of the radio set. If possible, the station should be located near moist ground, which has much less resistance. Water, and in particular salt water, will greatly increase the distances that can be covered.

(3) Trees with heavy foliage absorb radio waves, and leafy trees have more of an adverse effect than evergreens. The antenna should be kept clear of all foliage and dense brush.

b. Man-Made Obstructions.

(1) A position in a tunnel or beneath an underpass or steel bridge (fig. 50) should not be selected. Transmission and reception under these conditions are almost impossible because of high absorption of RF waves.

(2) Buildings located between radio stations, particularly steel and reinforced concrete structures, hinder transmission and reception.

(3) All types of pole wire lines, such as telephone, telegraph, and high-tension power lines, should be avoided when selecting a site for a radio station. Such wire lines absorb power from radiating antennas located in their vicinity. They also introduce hum and noise interference in receiving antennas.

(4) Positions adjacent to heavily traveled roads and highways should be avoided. In addition to the noise and

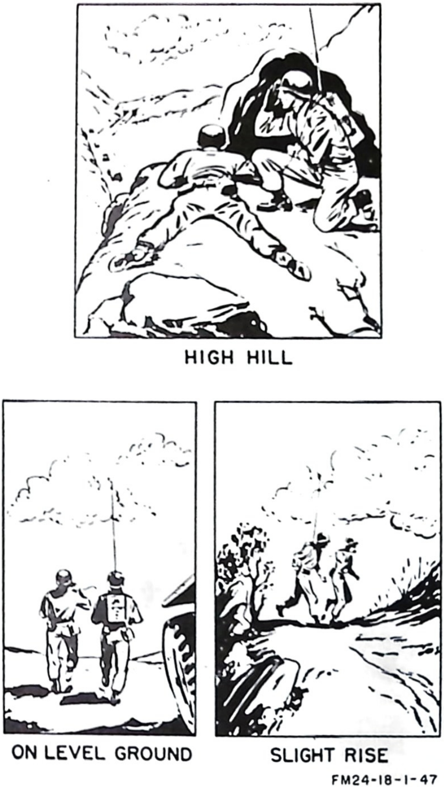

Figure 49. GOOD sites for radio communication.

confusion caused by tanks and trucks, ignition systems in these vehicles may cause electrical interference.

(5) Battery-charging units and generators should not be located close to the radio station.

(6) Radio stations should not be located close to each other.

(7) Radio stations should be located in relatively quiet areas. The copying of weak signals requires great concentration by the operator, and his attention should not be diverted by extraneous noises.

76. Tactical Requirements

a. Local Command Requirements. Radio stations should be located some distance from the unit headquarters or command post

Figure 50. BAD sites for radio communication.

that they serve. Thus, long-range enemy artillery fire, missiles, or aerial bombardment, directed at the stations as a result of enemy direction finding, will not strike the command post area.

b. Cover and Concealment. The locations selected should provide the best cover and concealment possible, consistent with good transmission and reception. Perfect cover and concealment may impair transmission and reception. The amount of permissible impairment depends upon the range required, the power of the transmitter, the sensitivity of the receiver, the efficiency of the antenna system, and the nature of the terrain. When a set is being used to communicate over a distance that is well under the maximum range, some sacrifice of communication efficiency can be made to permit better concealment of the set from enemy observation.

c. Practical Considerations.

(1) Pack sets have sufficiently long cordage to permit operation from cover, while the radio set is below the surface of the surrounding terrain and the antenna is in the clear.

(2) Some sets can be controlled remotely from distances of 100 feet or more. Sets of this type can be set up in a relatively exposed position, while the operator remains concealed.

(3) Antennas of all radio sets must extend above the surface of the ground to permit normal communications.

(4) Small tactical set antennas are usually of the whip type. These antennas are difficult to see from a distance, especially if they are not silhouetted against the sky.

(5) Open crests of hills and mountains must be avoided. A slightly defiladed position just behind the crest gives better concealment and sometimes provides better transmission.

(6) All permanent and semipermanent positions should be properly camouflaged for protection against both aerial and ground observation. However, the antenna should not touch trees, brush, or camouflage material.

d. Local Communications. Contact must be maintained between the radio set and the message center at all times, either by local messenger or field telephone. The station should also be readily accessible to the unit commander and his staff.

77. Final Considerations

It is almost impossible to select a site that will satisfy all tech-

nical and tactical requirements for a radio set. Therefore, a compromise is usually necessary and the *best* site available is selected. It is also a good idea to select both a primary and an alternate site. Then, if radio communication cannot be established at the primary location, the set can be moved a short distance to the alternate position.

Section II. RELIABILITY FACTORS AT TRANSMITTER

78. Frequency

The ground wave is used for most field radio communications. The range of the ground wave becomes correspondingly shorter as the operating frequency of the transmitter is increased through the applicable portions of the medium-frequency band (300–3000 KC) to the high-frequency band (3–30 MC). When the transmitter is operating at frequencies above 30 MC, distances are limited generally to slightly more than line-of-sight. For circuits using sky-wave propagation, the particular frequency to be selected depends on the climate, season, and time of day.

79. Power

The range of the transmitted signal is proportional to the power radiated by the antenna. An increase in power results in some increase in range, and a power decrease reduces the range. Under normal operating conditions, the transmitter should feed only enough power into the radiating antenna to establish reliable communication with the receiving station. Transmission of a signal more powerful than required is a breach of signal security because the position of the transmitter may be more easily fixed by enemy direction-finding stations. Also, the signal may interfere with friendly stations operating on the same frequency.

80. Antenna

For maximum transfer of energy, the radiating antenna must be the proper length for the operating frequency. The local terrain determines, in part, the radiation pattern, and therefore affects the directivity of the antenna and the possible range of the set in the desired direction. If possible, several variations in the physical position of the antenna should be tried to determine the optimum operating position, so that the greatest energy will be radiated in the desired direction.

81. Capabilities of Operators

The skill and technical capabilities of the operators at the transmitter and receiver play important parts in obtaining the maximum range possible. In many cases, the transmitter, output coupling, and antenna feeder circuits must be tuned correctly to obtain maximum power output. In addition, both the radiating antenna and the receiving antenna may have to be constructed properly with regard to both electrical characteristics and conditions of the local terrain.

Section III. RELIABILITY FACTORS IN TRANSMISSION PATH

82. Conductivity and Height of Intervening Terrain

a. Conductivity. The type of terrain between two field radio sets determines ground conductivity and affects the ground wave. Flat prairie country has high conductivity, for there is little absorption of the ground wave by the earth. Large surfaces of water also have high conductivity. Mountainous, rugged, and broken country usually has low conductivity. In areas where there are large mineral deposits, deep ravines, or valleys, the ground wave may be absorbed completely by the earth.

b. Height. Large terrain obstructions between transmitting and receiving stations reduce the reliability of radio transmission.

83. Distance Between Stations

Low power radio transmitters of limited range must work with receivers located within this range. Higher power transmitters with correspondingly stronger ground and sky waves may reach receiving stations with either or both of these waves, depending upon the distance between the transmitter and the receiver.

84. Skip Distance Factor

When sky wave propagation is used for communications, the characteristics of the skip distance must be considered. At certain times during the day or night on certain frequencies, the receiving station could lie within the skip zone and would not, therefore, receive a signal from the transmitter.

Section IV. RELIABILITY FACTORS AT RECEIVER

85. Sensitivity and Selectivity of Receiving Set

Sensitivity is the degree of response of a radio circuit to signals of the frequency to which it is tuned. Selectivity is the degree

to which a receiver is capable of differentiating between the desired signal and signals of other frequencies. A receiver must be properly alined and efficiently operated if the maximum values of sensitivity and selectivity are to be achieved. The inherent noise level of the circuit is a limiting factor in the sensitivity of a receiving set.

86. Receiving Antenna

In field radio communication, the type of construction, location, and electrical characteristics are not as decisive in the operation of the receiving antenna as they are in the transmitting antenna. The receiving antenna must be of sufficient length, be properly coupled to the input of the receiver circuit, and, in some cases, have the same polarization as the transmitting antenna.

87. Interference from Natural Sources

a. Radio interference from natural sources may be divided into four classifications:

(1) Atmospheric interference from electrical storms.

(2) Solar and cosmic interference from eruptions on the sun and other stars.

(3) Precipitation static from charged precipitation particles in the atmosphere. Particles may be rain, sleet, snow, sand, smoke, or dust. Dry particles produce greater charges than wet ones.

(4) Fading from disturbances in the medium through which radio waves are propagated.

b. Interferences listed above appear in electronic equipment as disturbing noise. This noise shows up as sound in headphones and loudspeakers, and as errors in the output of other terminal equipment. There is interference at most frequencies, but it diminishes considerably as the frequency is increased. Reception at very high frequencies suffers little from these disturbances.

88. Man-Made Interference

a. Man-made interference is generated by electrical devices, such as vehicle ignition systems, sparking brushes on motors and generators, and other rotating machines. If this interference is not controlled, it will drown out or obscure the transmission of intelligence.

b. Although man-made interference is best eliminated or minimized at its source, some improvements can be made at the re-

ceiver. The use of a directional receiving antenna will eliminate some of the interference if the source is not in the same direction as the transmitting station. In addition, specially designed antenna lead-in wire may eliminate or minimize man-made interference that would normally be picked up on the lead-in wire.

89. Mutual Interference

a. When one communication system interferes with another, or when one particular unit within a given system interferes with other units in the same system, there is a condition of mutual interference.

b. Mutual interference may appear in several forms—noise, crosstalk, and harmonic interactions. Some of the common conditions that cause mutual interference are as follows:

(1) Spurious, undesired signals.
(2) Spurious receiver responses.
(3) RF arcing in transmitters.
(4) Impedance mismatch in the antenna system.
(5) High-voltage pulse interference.
(6) Improper frequency assignments.

c. Interference originates from many local and distant sources. Frequency relationships, geographical location, faulty adjustment of equipment, improper operating techniques, and weather conditions are important factors contributing to the nature of mutual interference. Equipment and systems that are potential generators of mutual interference are radar, radio, radio aids to navigation, and telephones.

90. Capabilities of the Receiving Operator

Most communication receivers are provided with adjustable controls designed to minimize the adverse effects of fading, noise, and interference. The proficient use of these controls, such as the noise limiter and one of the various types of filters, often will permit satisfactory reception of many messages that would otherwise be lost when noise and interference become excessive. On the other hand, misadjustment of these controls, either through ignorance or carelessness, can cause unsatisfactory operation. Therefore, the skill and technical proficiency of the receiver operator play an important part in radio signal reception.

CHAPTER 7

RADIO OPERATING TECHNIQUES

Section I. INTRODUCTION

91. General

a. The tactical effectiveness of any communication equipment is no greater than the skill of the operators. The most efficient communication within a net or command is attained when the operators of the equipment habitually use the proper procedures in the transmission and reception of messages.

b. The information in this chapter pertains to the operation of radiotelegraph (International Morse Code), radiotelephone (voice), and radio teletypewriter (RATT) communications.

92. Operating Instructions

Instructions pertaining to radio communications are contained in the standing operating procedures (SOP), signal operation instructions (SOI), and standing signal instructions (SSI). The SOI outlines the organization of stations into nets, assigns call signs, designates net control stations (NCS), assigns frequencies, and provides information on changes to alternate frequencies and authentication. Security procedures to be adopted by radio operators in the command are included in the SSI. The SOP governs routine operations of a unit. Refer to FM 24–16 for additional information concerning the SSI, SOI, and SOP.

93. Operating Hints for Operators

a. Use a handset or headset, rather than a loudspeaker, if the incoming signal is weak.

b. Make sure that the microphone or handset is in good condition. Speak directly into the microphone; speak slowly and distinctly.

c. If the radio set is in a vehicle, make sure that the battery voltage is up. Keep the engine running to charge the battery.

d. Move the set or the vehicle, if necessary, to improve reception.

e. Upon approval of supervisor, use continuous-wave radio-telegraph rather than radiotelephone or radio teletypewriter communications to increase the range of the set.

f. Note that lack of communication or poor communication may be caused by—

(1) Too great a distance between radio sets.
(2) Poor choice of location (siting) at one or both ends of the circuit.
(3) Terrain—hills or mountains.
(4) Noise and interference.
(5) Not enough transmitter power.
(6) Defective equipment.
(7) Improper adjustment of equipment.
(8) Ineffective antenna.
(9) Improper frequency assignment.

g. Note that poorly maintained equipment and improper operation can be just as effective in preventing communication as excessive distances or mountainous terrain. It is imperative that the following precautions be observed at all times:

(1) Study, and become familiar with, the technical manuals for the pertinent sets. They outline complete operating instructions and maintenance procedures.
(2) Keep the radio set clean and dry.
(3) Handle the radio set carefully.

h. Set up routine inspection and maintenance procedures for the following:

(1) Keep plugs and jacks clean.
(2) Make sure that antenna insulators are dry, clean, and free of paint.
(3) Insure that antenna connections and power connections are tight.
(4) Check knobs and controls to insure that they operate easily without binding.
(5) Make sure that motors and fans run smoothly.
(6) Make sure that dry batteries are fresh and, remove batteries when the equipment is in storage or not in use.

Section II. GENERAL OPERATING INSTRUCTION

94. General

Before operating any radio set, obtain the equipment manual and carefully study the instructions covering the operation. Panel

diagrams, connection diagrams, and the paragraphs covering the description of components should be referred to during the preliminary starting procedure to insure that the proper cables are connected to the proper panel connectors, and that the controls are at their proper settings. Even the most experienced operators should check their preliminary procedures against these references from time to time to insure accuracy and to avoid damage to equipment. Refer to the operational checklist (and when authorized, the equipment performance checklist) to determine what performance should be expected from the equipment, and what action should be taken to remedy unusual occurrences during starting procedures and operation. The checklist provides guidance in the application of corrective measures if the set is not performing normally.

95. Steps in the Operation of a Radio Set

The radio sets that are issued to units will vary in type according to the communication requirements of the unit. For example, some sets may be completely contained in one assembly, while others may consist of separate components that must be properly connected together in order to assemble a complete radio set. The following steps are generally required in operating a radio set:

a. Check the Set for Completeness. Make sure that all the necessary components and accessories are on hand and ready for use. Refer to the equipment technical manual.

b. Check the Condition of the Knobs, Dials, Switches, and Controls. Look for knobs, dials, switches, and controls that are loose on their shafts, bind when being operated, are bound so that they won't operate, or are damaged in any other way. Make corrections where possible, or report the faulty condition. Make sure that all knobs and exterior parts are on the set. Report immediately any that are missing.

c. Check the Condition of Plugs, Receptacles, and Connectors. Do not attempt to connect the set for operation until you are sure that the plugs and connectors are clean and in good condition, and that the receptacles to which they must be connected are clean and in good condition.

d. Check the Connection Diagrams in the Equipment Manual before Making Connections. The connection diagrams show the type and number of cables required to connect the components of the radio set together for each type of operation. The radio

set can be damaged if cables are connected in the wrong receptacles.

(1) If the connectors don't match, it is possible to physically damage the pins or sleeves of the connectors.

(2) If a cable is connected to a receptacle into which it will fit, but where it does not belong, it is possible to cause serious electrical damage to the equipment and, in some cases, injury to the operator.

e. Check Dial, Switch, and Control Settings. Some radio sets can be seriously damaged if the switches, dials, and controls are not set to the required initial settings before applying power or making the initial tuning adjustments. Before turning on power, check the equipment manual to be sure that all preliminary starting procedures have been covered completely.

f. Check the Starting Procedure in the Equipment Manual. The equipment manual covers in detail the proper procedure for starting the radio set. If there is a specific sequence for starting the set, it is described in the manual. Perform the operations in the proper sequence.

g. Apply Power. After the proper connections have been made and all switches, dials, and controls have been properly set, power may be applied tc the set. Refer to the starting procedure in the equipment manual.

h. Allow the Set to Warm Up. All radio sets that use electron tubes require a warm-up period to permit the tubes to reach their efficient operating condition. In some cases, it is possible to damage a set by attempting to operate before the tubes are properly warmed up. Most sets are protected against such damage, but it is foolish to risk damage to a radio set by trying to put it on the air before it is ready.

i. Watch for Abnormal Operation during Warm-Up. From the time that the power is turned on until the radio set is warmed up and ready to operate, observe all indicators, meters, and dial lamps. If any of these indicate an unusual condition, investigate immediately. Circuit breakers are provided on most sets to protect against burn-outs caused by overloads, but other malfunctions can occur that will not trip the circuit breaker. These other malfunctions can also damage the set.

j. Tune the Set to the Desired Frequency (Channel). Tune the transmitter to its proper frequency (the frequency of the desired channel) according to the procedures described in the equipment

manual. Use the methods that are given in the equipment manual to check for correct tuning.

k. Check the Set for Normal Operation. While the set is in operation, check the indicators frequently to be sure that the set is operating correctly. If anything unusual occurs in the operation, investigate it immediately. If necessary, turn off the power to the set and refer to the operational checklist and the equipment performance checklist in the equipment manual. If the corrections given in the operational checklist and the equipment performance checklist will not correct the trouble, report the set's condition to the unit communication-electronic equipment repairman. Make sure that the condition of the set and the action taken are properly recorded on the maintenance records.

l. Use the Proper Procedure to Turn the Set Off. After operation has been completed, or if the set is being turned off because of improper operation, make sure that the controls, switches, and dials are properly positioned (this may not be required on some sets) and proceed to shut down the components of the set in the sequence specified in the equipment manual. Simple sets may require nothing more than turning the power switch to its off position, but more complex sets may require elaborate shut-down procedures.

Section III. RADIOTELEGRAPH PROCEDURE

96. General

Radiotelegraphy is a system of telecommunication for the transmission of intelligence (or information) by International Morse Code. It provides the most reliable radio communication over long distances and under adverse conditions, but requires highly skilled operators. It is used to and between mobile units and as an emergency substitute for teletypewriter. Details on radiotelegraph procedure are in the ACP 124 ( ) series.

a. Brevity Codes in Radiotelegraphy. In addition to normal communication procedures, radiotelegraphy utilizes prosigns, operating signals, and special abbreviations. Operating signals are listed in ACP 131; authorized prosigns and abbreviations are n ACP 124 ( ).

b. Advantages of Radiotelegraphy. Although code communication is necessarily slower than voice or teletypewriter communication, it has the advantage of being more readable in the presence of accidental interference and jamming. Code signals can often be read clearly when voice or teletypewriter signals

of the same strength are unreadable. A defective AM voice transmitter that cannot be used for voice transmission can sometimes be operated quite effectively as a CW transmitter.

97. International Morse Code

Dots and dashes are used in various distinctive combinations to represent the letters of the alphabet, the numerals from Ø to 9, and the procedure signs (prosigns). The dots and dashes of the Morse Code are produced by keying a transmitted and causing it to transmit short and long signals. The dash is three times the length of the dot. The combination of dots and dashes that are used for a letter are spaced from each other by a period of time equal in length to one dot. Letters are spaced from each other by a period of time equal to three dots and words are spaced by a period of time equal to seven dots.

98. Procedure Signs

Procedure signs (prosigns) are used on radiotelegraph and radioteletypewriter circuits to convey information, requests, orders, and instructions in a condensed standardized form. Prosigns represent single words or phrases in order to minimize transmitting time. Radiotelegraph transmitting operators will send the overscored letters of a prosign together without character spacing. Authorized prosigns and their meanings are listed in the chart below.

Prosign	Meaning
AA	ALL AFTER
[a] $\overline{\text{AA}}$	UNKNOWN STATION
AB	ALL BEFORE
$\overline{\text{AR}}$	END OF TRANSMISSION
$\overline{\text{AS}}$	WAIT
B	MORE TO FOLLOW
$\overline{\text{BT}}$	LONG BREAK
C	CORRECT
[b] CFN	CONFIRMATION
DE	FROM
EEEEEEEE	ERROR
F	DO NOT ANSWER
FM	ORIGINATOR'S SIGN
G	REPEAT BACK
GR (numeral)	GROUP COUNT
GRNC	GROUPS NOT COUNTED
$\overline{\text{HM}}$ (3 times)	EMERGENCY SILENCE SIGN
[a] II	SEPARATIVE SIGN
$\overline{\text{IMI}}$	REPEAT
INFO	INFORMATION ADDRESSEE SIGN

See footnotes on p. 86.

Presign	Meaning
$\overline{\text{INT}}$	INTERROGATORY
$\overline{\text{IX}}$	EXECUTE TO FOLLOW
[c] IX (5-second dash)	EXECUTIVE SIGNAL
J	VERIFY AND REPEAT
K	INVITATION TO TRANSMIT
NR	NUMBER
O	IMMEDIATE
P	PRIORITY
R	RECEIVED
R	ROUTING
T	TRANSMIT TO
TO	ACTION ADDRESSEE SIGN
WA	WORD AFTER
WB	WORD BEFORE
XMT	EXEMPTED ADDRESSEE SIGN
Z	FLASH

[a] Radiotelegraph prosign.

[b] Radioteletypewriter prosign.

[c] In lieu of IX (5-second dash) on radioteletypewriter circuits, type "EXECUTE" as the executive signal.

99. Operating Signals

Operating signals, which are three-letter signals starting with the letter Q or the letter Z, are used by CW operators (and radio teletypewriter operators) to expedite communications. Each Q-signal or Z-signal conveys the meaning of a number of words and, at times, a complete message. For example, ZFG means, "This message is an exact duplicate of a message previously transmitted." Information on the authorization of Q-signals and Z-signals is presented in ACP 131.

a. ACP 131 lists the meanings of Q-signals and Z-signals and provides instructions for their use. If it is not possible to provide each operator with a copy of ACP 131, lists of commonly used Q-signals and Z-signals should be prepared and provided to each operator. In no case should the operator be required to memorize all of these operating signals.

b. Operating signals are considered to be plain language, and they must be encrypted when used as part of an encrypted message. They are an aid to communication security, since they are brief, but their meanings are common knowledge to many nations.

Section IV. RADIOTELEPHONE PROCEDURE

100. General

Radiotelephony is a system of telecommunications that is normally used for short-distance tactical communication and between mobile and air units. It provides rapid, person-to-person communication in highly mobile situations. However, radio transmissions are subject to enemy interception and afford little or no security to messages. Therefore, basic rules essential to transmission security are strictly enforced on all military radiotelephone circuits. Details on radiotelephone procedures are in the ACP 125 ( ) series.

a. Brevity Codes in Radiotelephony. Whereas radiotelegraphy makes use of prosigns and operating signals, radiotelephony utilizes procedure words (prowords) and procedure phrases. Authorized prowords are covered later in this section.

b. Calls. When communicating in a radiotelephone net, one of the following calls is used:

(1) Full call: DANO THIS IS BUTTER DIESEL OVER
(2) Abbreviated call: THIS IS BUTTER DIESEL OVER
(3) Net call: BUTTER DIESEL THIS IS BUTTER DIESEL 6 OVER

c. Operating Rules. When using radiotelephone, the operator must—

(1) Listen before transmitting to avoid interference with other traffic.
(2) Speak in natural phrases, not word by word.
(3) Speak slowly and distinctly.

101. Pronunciation of Letters and Numerals

To avoid confusion and errors during voice transmissions, special procedures have been developed for pronouncing letters and numerals. These special procedures are the phonetic alphabet and phonetic numerals.

a. The phonetic alphabet is used by the operator to spell difficult words and thereby prevent misunderstanding on the part of the receiving operator. The words of the phonetic alphabet, which is a word alphabet and not a code, are pronounced as shown in the chart in *c* below. The underscored portion indicates the syllable or syllables to be emphasized.

b. The word that might be misunderstood is spoken if it can be

pronounced; spelled out phonetically; and then spoken again. For example, "PIDCOKE, I SPELL—PAPA INDIA DELTA CHARLIE OSCAR KILO ECHO—PIDCOKE."

c. The phonetic alphabet is also used for the transmission of encrypted messages. For example, the cipher group CMVVX is spoken, "CHARLIE MIKE VICTOR VICTOR XRAY."

Phonetic alphabet

Letter	Word	Pronunciation	Letter	Word	Pronunciation
A	ALFA	AL FAH	N	NOVEMBER	NO VEMBER
B	BRAVO	BRAH VOH	O	OSCAR	OSS CAH
C	CHARLIE	CHAR LEE	P	PAPA	PAH PAH
D	DELTA	DELL TAH	Q	QUEBEC	KEH BECK
E	ECHO	ECK OH	R	ROMEO	ROW ME OH
F	FOXTROT	FOKS TROT	S	SIERRA	SEE AIR RAH
G	GOLF	GOLF	T	TANGO	TANG GO
H	HOTEL	HOH TELL	U	UNIFORM	YOU NEE FORM
I	INDIA	IN DEE AH	V	VICTOR	VIK TAH
J	JULIETT	JEW LEE ETT	W	WHISKEY	WISS KEY
K	KILO	KEY LOH	X	XRAY	ECKS RAY
L	LIMA	LEE MAH	Y	YANKEE	YANG KEY
M	MIKE	MIKE	Z	ZULU	ZOO LOO

d. Numbers are pronounced as shown in the following chart.

Phonetic numbers

Number	Pronunciation	Number	Pronunciation
1	WUN	6	SIX
2	TOO	7	SEV-en
3	TREE	8	AIT
4	FOW-er	9	NIN-er
5	FIFE	0	ZE-RO

e. Numbers are spoken digit by digit, but the words "HUNDRED" or "TOUSAND" are used for even hundreds and thousands. For example, 84 is "AIT FOW-er;" 2,500 is "TOO FIFE HUNDRED;" and 16,000 is "WUN SIX TOUSAND."

f. The date-time group is always spoken digit by digit, followed by the time zone indication. For example, 291205Z is "TOO NIN-er WUN TOO ZE-RO FIFE ZOO LOO."

g. Map coordinates and call sign suffixes also are spoken digit by digit.

102. Procedure Words

To keep voice transmission as short and clear as possible, radio operators use procedure words (prowords) to take the place of long sentences. The prowords and their meanings are listed in the following chart.

Proword	Meaning
ALL AFTER	I refer to the portion of the message that follows ________.
ALL BEFORE	I refer to the portion of the message that precedes ________.
BREAK	I hereby indicate the separation of the text from other portions of the message. Or: I have completed the text of the message, signature follows, etc. (When "break-in" is permitted, receiving operator may interrupt the transmitting operator to request retransmission of a portion of a message. This proword is the interruption sign.)
CORRECTION	An error has been made in this transmission. Transmission will continue with the last word correctly transmitted. An error has been made in this transmission (or message indicated). The correct version is ________. That which follows is a corrected version in answer to your request for verification.
DISREGARD THIS TRANSMISSION	This transmission is in error. Disregard it. (This proword shall not be used to cancel any message that has been completely transmitted and for which receipt or acknowledgment has been received.)
DO NOT ANSWER	Stations called are not to answer this call receipt for this message, or otherwise to transmit in connection with this transmission. When this proword is employed, the transmission shall be ended with the proword "OUT."
EXECUTE	Carry out the purpose of the message or signal to which this applies. To be used only with the Executive Method.
EXECUTE TO FOLLOW	Action on the message or signal which follows is to be carried out upon receipt of the proword EXECUTE. To be used only with the Executive Method.
EXEMPT	The addressee designations immediately following are exempted from the collective call.
FIGURES	Numerals or numbers follow.
FLASH	Precedence FLASH.

Proword	Meaning
FROM	The originator of this message is indicated by the address designation immediately following.
IMMEDIATE	Precedence IMMEDIATE.
INFO	The addressee designations immediately following are addressed for information.
I READ BACK	The following is my response to your instructions to read back.
I SAY AGAIN	I am repeating transmission (or portion) indicated.
I SPELL	I shall spell the next word phonetically.
I VERIFY	The following message (or portion) has been verified at your request and is repeated. To be used only as a reply to VERIFY.
MESSAGE FOLLOWS	A message which requires recording is about to follow. (Transmitted immediately after the call.)
NUMBER	Station Serial Number.
OUT	This is the end of my transmission to you and no answer is required or expected.
OVER	This is the end of my transmission to you and a response is necessary. Go ahead; transmit.
PRIORITY	Precedence PRIORITY.
READ BACK	Repeat this entire transmission back to me exactly as received.
RELAY TO	Transmit this message to all addresses or to the address designations immediately following.
ROGER	I have received your last transmission satisfactorily.
ROUTINE	Precedence ROUTINE.
SAY AGAIN	Repeat all of your last transmission. Followed by identification data means "Repeat ________ (portion indicated)."
SIGNALS FOLLOW	The groups which follow are taken from Signal book. (This proword need not be used on nets primarily employed for conveying signals. It is intended for use when tactical signals are passed on nontactical nets.)
SILENCE	Cease transmission immediately. (Silence will be maintained until instructed to resume. When an authentication system is in force, transmissions imposing silence are to be authenticated.)
SILENCE LIFTED	Resume normal transmissions. (Silence can be lifted only by the station imposing it or by higher authority. When an authentication system is in force, transmissions lifting silence are to be authenticated.)

Proword	Meaning
SPEAK SLOWER	Your transmission is at too fast a speed. Reduce speed of transmission.
THAT IS CORRECT	You are correct, or what you have transmitted is correct.
THIS IS	This transmission is from the station whose designation immediately follows.
TIME	That which immediately follows is the time or date-time group of the message.
TO	The addressees whose designations immediately follow are to take action on this message.
UNKNOWN STATION	The identity of the station with whom I am attempting to establish communication is unknown.
VERIFY	Verify entire message (or portion indicated) with the originator and send correct version. To be used only at the discretion of or by the addressee to which the questioned message was directed.
WAIT	I must pause for a few seconds.
WAIT OUT	I must pause longer than a few seconds.
WILCO	I have received your message, understand it, and will comply. (To be used only by the addressee. Since the meaning of ROGER is included in that of WILCO, the two prowords are never used together.)
WORD AFTER	I refer to the word that follows ________.
WORD BEFORE	I refer to the word that precedes ________.
WORDS TWICE	Communication is difficult. Transmit(ting) each phrase (or each code group) twice. This proword may be used as an order, request, or as information.
WRONG	Your last transmission was incorrect. The correct version is ________.

Section V. RADIO TELETYPEWRITER PROCEDURE

103. General

Radio teletypewriter (RATT) is a system of telecommunications for the transmission of intelligence (or information) by direct action of a keyboard or perforated tape over AM radio circuits. This same intelligence (or information) may be received in the form of page copy, perforated tape, or both.

a. Advantages of field radio teletypewriter operations include, through the use of one mobile radio teletypewriter set, the avail-

ability of all three modes of radio telecommunication systems—radiotelegraph, radiotelephone, and radio teletypewriter. Transmission is possible over distances up to several thousand miles.

b. Radio teletypewriter operators must be highly trained in all three methods of operations. They must maintain their proficiency in radiotelegraph operations and must use this mode of transmission when the quality of the circuit drops below that required for radio teletypewriter communication.

c. Message format and the procedure for handling messages by radio teletypewriter are the same as that used for manual teletypewriter operations, which are prescribed in ACP 126. Refer to paragraph 98 for procedure signs.

104. Machine Functions

a. Shift. Operators must always depress the "LTRS" key when going from upper case to lower case and the "FIGS" key when going from lower case to upper case.

b. Carriage Return. The carriage return function (CR) resets the machine to the left margin of the paper. Two carriage return functions are used to insure the proper return of the carriage.

c. Line Feed. The line feed function (LF) advances the paper vertically on the page teletypewriter.

d. Space. The space function advances the typing unit laterally without printing a character on the page teletypewriter.

e. Bell Signal. The bell signal attracts the attention of the receiving operator when required and will be transmitted as a series of ten characters—upper case "J" and "S" as follows: "FIGS JJJJJSSSSS LTRS".

f. Warning Light. Tape perforating equipment is equipped with a warning-light to indicate the approach of the end of typing line.

g. Margin Bell. Page printers equipped with keyboard facilities capable of operating directly into the line provide a margin bell to indicate the approach of the end of typing line.

h. Specific Machine Functions. These functions are necessary to facilitate the handling of messages and to align receiving page teletypewriters.

(1) All transmissions must be preceded by five spaces, two carriage returns, and one line feed. After a preliminary call has been made and answers thereto received, the transmitting operator will make two carriage returns

and eight line feed functions before transmitting a message.

(2) The end of line functions will be two carriage returns and one line feed.

(3) The separative function between pages of long messages is two carriage returns and eight line feeds.

(4) The end of message functions are two carriage returns, eight line feeds, the letter N repeated four times, and twelve letters. When authorized by separate service instructions, the end of message functions may be altered to require two carriage returns and twelve letters.

(5) No line shall exceed 69 characters, including spaces, except when authorized for special purposes by separate service instructions.

105. Punctuation

a. Punctuation is not used unless it is necessary to the sense of a message. When it is essential to use punctuation, the following abbreviations and symbols are authorized.

Punctuation	Abbreviation	Symbol
Question Mark	QUES	?
Hyphen		-
Colon	CLN	:
Parenthesis	PAREN	( )
Period/Full Stop	PD	.
Comma	CMM	,
Slant/Oblique Stroke		/
Paragraph	PARA	None
Quotation Marks	QUOTE-UNQUOTE	None

b. The letter "X" may be used in lieu of punctuation whenever exact punctuation is not considered essential, but when some separation in the text is necessary for clarity and this use of "X" is not ambiguous. The written phonetic equivalent of the letter "X" will not be used for this purpose.

c. When a message is written in free hand, it may often be advisable to encircle the symbols for periods/full stops and commas to make them more conspicuous.

Section VI. TACTICAL CALL SIGNS

106. Purpose of Call Signs

Call signs are used primarily for establishing and maintaining communications. They consist of any combination of characters

or pronounceable words that identify a communication facility, a command, an authority, or a unit. Periodic changing of call signs provides communication security for a brief period, depending on the amount of use and the quality of the enemy's traffic analysis. Call signs that consist of four characters, such as 6B69 or DN8Z, are authorized for radiotelegraph (CW) and manual teletypewriter (including radio teletypewriter), and are used for voice operation on AM equipment. Voice call signs that consist of pronounceable words, such as BUTTER DIESEL or ACHING BUNKER, are authorized for radiotelephone operators.

107. Use of Call Signs

There are many times when a headquarters is given a single call sign for use in the different nets in which the headquarters is required to operate. When a single call sign is used for operation in both CW and radiotelephone nets, an assigned call sign such as XY24 is acceptable for radiotelephone use by pronouncing the letters phonetically: XRAY YANKEE TOO FOW-er. In some situations, when additional security is required, it is more desirable to use a different call sign for each net in which the station is to operate.

108. Net Call Signs and Collective Calls

When the attention of all stations in a radio net is desired, the net call sign is used. The use of this call sign facilitates net operation and is often used by the NCS to regulate net operation. A collective call is similar to a net call, but it is used to group two or more, but not all, of the net stations. A collective call is useful when several stations must be called frequently on matters that are of no concern to other net stations.

109. Alternate Call Signs

All call signs are changed periodically according to prearranged instructions. The period of time in which they remain in effect depends upon the degree of security desired. These instructions, with a scheduled list of call signs and alternate call signs, are published in the command SOI. A change of call signs involves a change in operating frequency, which is an additional countermeasure against enemy interception and traffic analysis.

110. Assignment of Call Signs

Care must be exercised in assigning call signs to individual stations in the same radio net. The assignment of unsuitable call

signs can result in confusion and inefficient net operation. For example, similar call signs, such as 6P7X, 6P6X, or A67P, are difficult to distinguish during periods of poor reception. The wrong operator, hearing only part of the call, might assume that the call is for him and add to the confusion by answering in place of the correct station. To avoid this, call signs should be assigned (within nets) with a minimum duplication of the same letters or numbers.

Section VII. AUTHENTICATION

111. General

a. Authentication is a security measure designed to protect a communications system against fraudulent transmissions. There are many circumstances in which authentication must be used, depending upon the needs or desires of each command. The policy of the commander is published in the SSI. Authentication tables are contained in the SOI.

b. There is more detailed information on authentication in KAG–24/TSEC, which should be held by all commands that publish an SSI and SOI. This publicationis obtained through cryptologistic channels.

112. Authentication Challenge and Reply

a. The chart below is a simple authentication table. The letters A to Z, printed in sequence on the left hand side of the table, are the *row designators*. The numbers 0 to 9, next to the letters, represent those letters. For example, if either of the two test elements of the challenge is a number such as 4, the adjacent letter E is used.

b. Assume that an operator is challenged with two test elements—HL. The correct method of authentication is to use the *first letter to the right* of the last test element. The following procedure is used to find the correct authentication.

(1) Locate the first test element, H, in the column of row designators.

(2) Scan across the row designated by H to find the second test element, L.

(3) The "first letter to the right" of L is A. Therefore, A is the authenticator and the challenged operator would reply ALFA.

c. If the second test element happens to be the last letter in the row, use the first letter in the same row as the authenticator.

Thus, U would be the authenticator if the test elements HO were used.

FOR TRAINING PURPOSES ONLY

Row designator	Sample authentication system No. ——— effective 0001 to 2400 hr, 1 March 65
Ø A	E C B X K Z O V J L M G S T F W I Y A D H P R Q N U
1 B	O T H P F W X K E D Z Y A L N S C J V B Q R M G I U
2 C	X N C E T S G Q R P H D Q Y I B W M J L V U O Z K F
3 D	T Z D E H W V J K X C A Y U I G S R Q O F B L N P M
4 E	W D V R H K X Y L N Z G E U B C J S T P M F I A O Q
5 F	M P N L B F O Q R S G I U Y A C X K J V W H E D Z T
6 G	J V U P C W O Z Y T K X S G Q E R I D A F M L N H B
7 H	U I G M R Q B V J C S N L A Y Z D E K X W F P H T O
8 I	B Q R T M G I U H P F S Y A C W K N X L E D Z O J V
9 J	B H N K M F A D I R Q G S X L T Y Z O W P U V J E C
K	K F M J P U N Y B H O A R X Z V D T C G W E S Q L I
L	Q R D A M X L N H K U I V P C J B F O S W E T Z Y G
M	H G M L D Y A T S Z K X B C O Q R P I W J V E U N F
N	V J O Z D E K X N L W C A Y S F P H U I G M T R Q B
O	A T J V E U O Q R P Y S Z K X B C I W N F H G M L D
P	M A D I K T E Q G V S O F B W H N L X Y Z J R C P U
Q	F N U E V J W I P R Q O C B X K Z S T Y A D L M G H
R	Z N T S Y J F U E C X B K W H I R Q O A V D L M P G
S	G Y Z T E W S O F B J C P V I U K H N L X M A D R Q
T	Q O A I F M P T S J C B U E G Z N L Y X K H R V D W
U	U P C R J Z Y X L N H W B F O S V G Q E T K I D A M
V	G P M L D V A O Q I H W K X B C E U F J Y S T N Z R
W	U N Q R P H D A Y I W F T S G M L J V O Z K X B C E
X	I L Q S E W G T D V C Z X R A O H B Y N U P J K M F
Y	D L M G H F N W I C B X K Z S Y P R Q O U E V J T A
Z	M P H O A R L G W E S Q K J X Z U N Y B V D T C I F

FOR TRAINING PURPOSES ONLY

d. Operators in a net must avoid repitition of the same pair of test elements when challenging. An enemy agent intercepting transmissions from a friendly station will have no trouble in determining the significance of the authentication test elements. Once he has learned the proper reply to a set of test elements, he can use imitative deception to enter the net. Thus, carelessness on the part of the operator can result in compromise of the authentication system.

Section VIII. WORLD TIME ZONES AND TIME CONVERSION TABLE

113. General

The date and time in messages are expressed as six digits, followed by a time zone suffix. The first pair of digits denotes the date, the second pair the hour (24-hour clock), the third pair the minutes. Example of a date time group with a zone suffix is 201132Z.

114. Greenwich Civil Time

Greenwich Civil Time (GCT) is accepted as the basis for measuring time throughout the world. The time zone suffix Z, which expresses GCT time, follows immediately the last digit of the date time group. Any other suffix letter, used after a four-digit time group, indicates the zone in which the local time is expressed. The proper suffix can be determined from the time zone map (fig. 51).

Figure 51. World time zone map.
(Located at back of manual)

115. World Time Zone Map

Numerals in the lower portion of the time zone map (fig. 51) indicate the difference in hours between local time and Z time. Local civil time can be changed to Z time by adding or subtracting the appropriate number of hours indicated in the time zone map. Deviation in times from those shown in figure 51 may occur because of local policies or conditions.

116. Time Conversion Table

A time conversion table (fig. 52) is used to convert local time in one zone to local time in any other zone. The vertical columns indicate specific time zones. When the time is known in any of the time zones, the corresponding time in any other zone can be determined by using the horizontal columns. Time in the shaded area to the right of the chart is one day (24 hours) later; to the left is one day (24 hours) earlier. To use this conversion table, proceed as follows: Assume that the local time in R time zone (1600 hours, 17th day) is to be converted to local time in the Z zone. Find 1600 in column R and proceed across the horizontal column to the same line in column Z. The local time in the Z zone is 2100 hours on the 17th day. If I zone rather than Z zone is desired, the local time in I zone is 0600 on the 18th day.

	Y +12	X +11	W +10	V +9	U +8	T +7	S +6	R +5	Q +4	P +3	O +2	N +1	Z 0	A −1	B −2	C −3	D −4	E −5	F −6	G −7	H −8	I −9	K −10	L −11	M −12	
PREVIOUS DAY	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	SAME DAY
	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	
	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	
	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	
	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	
	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	
	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	
SAME DAY	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	NEXT DAY
	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	
	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	
	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	
	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	
	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	
	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	
	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	
	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	
	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	
	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	
	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	
	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	
	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	
	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	
	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	
	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	

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Figure 52. Time conversion table.

Section IX. RADIO NETS

117. General

Field radio stations are normally grouped into nets according to the requirements of the tactical situation. Each net is assigned one or more definite frequencies on which to operate.

a. For the purpose of controlling a radio net, one station, usually the one serving the highest headquarters within the net, is designated the net control station (NCS). The authority of the NCS covers only the operation of the net and its discipline while on the air and during periods of listening silence.

b. Since the NCS has responsibility for maintaining communication discipline within the net, the NCS operator has the authority to exercise the degree of operational control deemed necessary to insure the most efficient use of the net's assigned circuits. However, he does not have a voice in the internal administration of a station, its tactical operation, or its movement. For example: the brigade NCS of an infantry unit cannot prescribe locations for battalion stations in the net nor can the NCS operator prescribe the hours at which station operators will be relieved by other operators. These and similar administrative functions are controlled by each unit concerned. Figures 53 and 54 illustrate organizations of typical radio nets.

118. Net Control

The authority of the NCS is absolute within its scope of technical control. It opens and closes the net, controls transmissions and clears traffic within the net, corrects errors in operating procedures, gives or denies permission for stations to enter or leave the net, and maintains net discipline. The extent of control exercised by the NCS varies according to operating conditions. In a net where experienced operators are passing traffic smoothly, little formal control is required. When the volume of traffic is great and operators are less experienced, the NCS may be required to exercise firm control to keep the net organized and traffic flowing in an orderly manner.

119. Types of Nets

a. In a free net, traffic is exchanged without prior permission from the NCS.

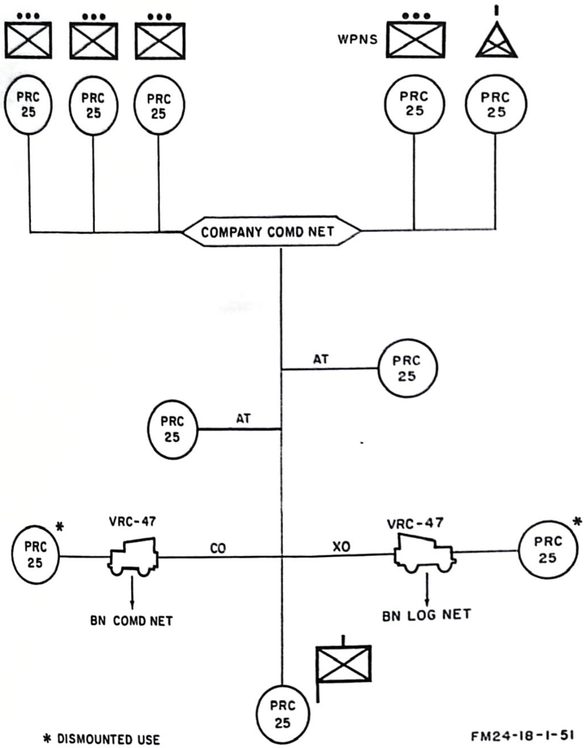

Figure 53. Typical company radio net.

b. In a directed net, stations obtain permission from the NCS before transmitting. When more than one station has traffic to transmit in a directed net, the NCS decides which station has priority, according to the precedence involved.

120. Functions of the NCS

a. To Open a Net. To open a net, the NCS sets its transmitter frequency to the assigned net frequency. Using the net call, the NCS calls the stations assigned to the net and identifies itself as

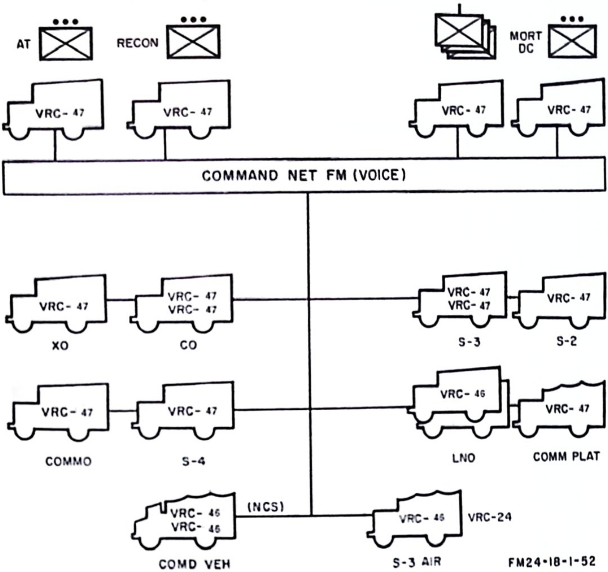

Figure 54. Typical battalion radio net.

the NCS. After the called stations reply in alphabetical order, the NCS states that their transmissions have been heard. The NCS then declares the condition of the net (free net, directed net, listening silence, etc.).

b. To Close a Net. To close a net, the NCS uses the net call and declares that the net is closed. If the net is to re-open later, the NCS informs the stations of the net at what time and on what frequency the net will re-open. This information may be set up by a prearranged message code, or by reference to an SOI that contains the information.

c. To Admit a Station to the Net. When a station desires to join an existing net, it is required to request permission from the NCS to do so. The station first transmits the NCS station call sign, and then transmits its own call sign. After the NCS acknowledges the call, the requesting station states its reasons

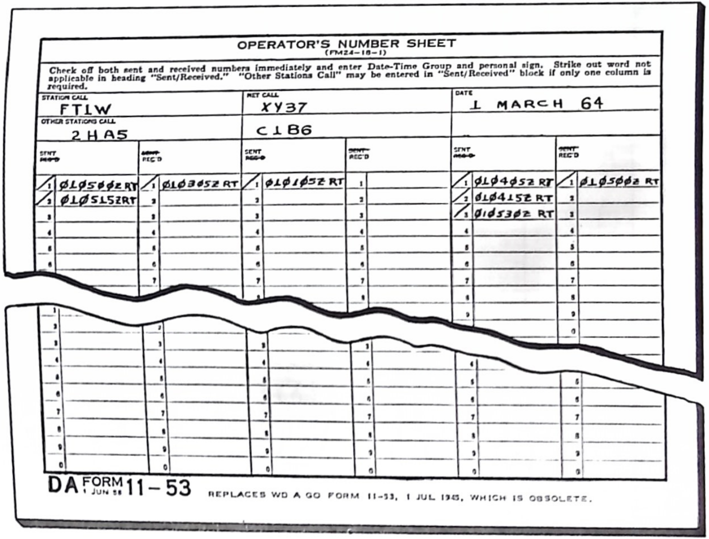

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Figure 55. Front of operator's number sheet.

for desiring admission to the net. The NCS will challenge the station with test elements of the authentication system to verify the identity of the station. After the identity of the station is established, the NCS will either grant or refuse the request. This decision is rendered after the NCS considers the validity of the station's reason for entering the net.

d. To Release a Station from the Net. A station desiring to leave the net will call the NCS and request permission to do so. NCS will grant permission if the reason for the request is valid.

e. To Monitor the Net. The NCS keeps its receiver on the air at all times to monitor the net. If any station violates the net operating procedures, the NCS corrects the infraction. The NCS also keeps constant watch on the flow of message traffic within the net and is prepared to take necessary action to expedite message traffic when there is a conflict or interference among stations.

f. To Control and Schedule Transmissions. When traffic within a net is heavy, the NCS may be required to exercise close control over the transmissions and disciplinary control to prevent unnecessary transmissions. The NCS may also establish daily schedules for routine traffic and direct the net in such a manner tha the most important messages are transmitted in order of prece dence.

g. To Impose or Lift Listening Silence. The NCS upon authorization by competent authority, will impose listening silence or lift listening silence when the tactical situation requires it. The NCS imposes listening silence by calling all stations of the net and informing them that listening silence is in effect. It is then the responsibility of the NCS to insure that no transmissions take place within the net until listening silence is lifted. To lift listening silence, the NCS calls the station or stations permitted to transmit and states the conditions under which listening silence is lifted.

h. To Direct the Net. When traffic is heavy, or when operators are inexperienced in handling net traffic, the NCS may order a directed net. In this case, no station will transmit without first calling the NCS and requesting permission to transmit. The NCS may require the station to state the nature and class of the message, and its destination, before granting permission for transmission. Under the condition of a directed net, the NCS will also

establish the net procedures to be followed by all stations in the net.

121. Tuning to Net Frequency (Netting)

To communicate from one radio station to another, the radio receiver must be tuned to the frequency at which the distant radio transmitter is sending. With certain types of radio equipment, the frequencies or channels are usually preset by maintenance personnel; other radio sets may require presetting or tuning to the assigned frequency by the operators. It is important to tune the radio set to the exact frequency. The NCS uses a standard, such as a frequency meter or a crystal-controlled oscillator, to insure that the frequency of its net is correct. When operating a secondary or subordinate station in a net, the receiver is tuned to the NCS transmitting frequency and then the receiver is used as the standard to tune the transmitter. The NCS is responsible for having its transmitter tuned to the assigned frequency. Each subordinate station must tune to the NCS even if the NCS is off frequency. In such instances, the subordinate station should inform the NCS. For further information, refer to ACP 124B, ACP 125B, and ACP 126.

Section X. STATION SOP

122. General

Radio stations should establish operating procedures for the handling of messages and the maintenance of station records. These station operating procedures are established to meet the requirements of the unit or organization served by the station.

123. Message Preparation

a. All messages should be written out before transmission in order to use circuit time more efficiently and to provide a record copy of each message. Military messages should be written as concisely as possible without losing clarity.

b. Message forms should be used when available. These are issued in book form for use by field units in tactical operations. The Field Message Book, M–210, is procured from AG publications sources as DA Form 11–170.

c. Information on message writing is contained in AR 105–31 and FM 24–17. Information on message precedence is included in ACP 121 US SUPP (A)–1 (CLASSIFIED).

124. Operator's Duties

a. The radio operator must always use the prescribed radio procedure. Unauthorized changes in procedures invariably create confusion, reduce reliability and speed, and decrease communication security.

b. Before an operator turns over his station to the operator who relieves him, he should pass on to his relief special orders and information concerning the station. This should include all necessary or useful information concerning messages awaiting transmission, changes in radio net organization, performance of the equipment during the previous period of operation, and other pertinent data.

c. Before taking over the station, the relieving operator should check the transmitter and the receiver to insure that they are in efficient operating condition and are properly tuned to the assigned frequency.

d. Radio operators will improve radio communication if they observe the following general rules:

(1) Listen prior to transmitting to avoid interference with the transmissions of other stations.

(2) Make transmissions as brief as possible to keep the net clear for traffic.

(3) Send call signs clearly and accurately.

(4) Transmit at the speed of the slowest operator in the net.

(5) Maintain an alert watch for net and station calls, and reply promptly to all transmissions requiring a reply.

(6) Operate at the minimum power required to maintain communication with all stations in the net.

(7) Use only prescribed radio procedures, and conform with the regulations for maintaining transmission security.

125. Operator's Number Sheet

a. The Operator's Number Sheet (DA Form 11–53) (figs. 55 and 56) is used by the radio operator to keep a record of incoming and outgoing messages. These numbers can be used conveniently as station serial numbers. The station serial numbers should not be transmitted with the message; they are used to assist in handling, recording, and checking traffic within a station.

b. Each radio station should maintain a separate series of station serial numbers for each station with which it communicates.

LOG

Enter opening and closing time, frequencies, frequency checks and frequency changes, traffic delays and any incidents or conditions affecting circuit efficiency. Remarks need not be confined to one line.

STATION—~~CIRCUIT~~—NET (Strike out words not applicable): FT1W - XY37

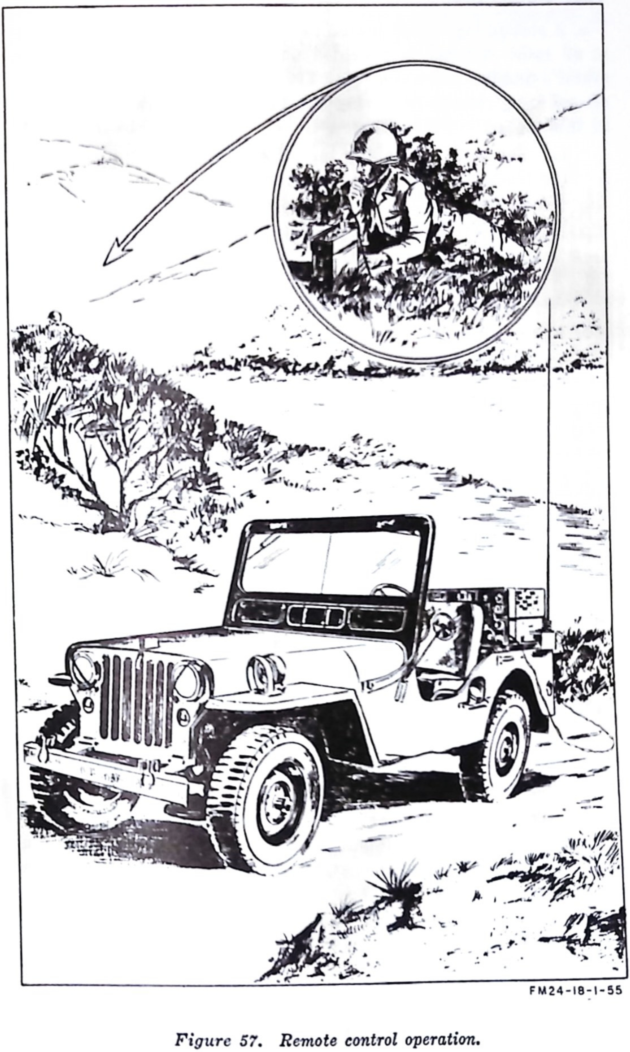
DATE: 1 March 64

TIME	OPERATOR'S SIGN	REMARKS
0755Z	JD	PVT JOHN R DAVISON ON DUTY
0810Z	JD	XY37 DE FT1W ZNB WH BB INT ZNB BL K
		XY37 DE 2HA5 ZNB YY INT ZNB OT K
		XY37 DE C1B6 ZNB MM L
0812Z	JD	XY37 DE FT1W R AR
	JD	2HA5 DE FT1W P K
		FT1W DE 2HA5 K
		2HA5 DE FT1W -P- 010737Z
		FT1W DE 2HA5 IMI 6 K
		2HA5 DE FT1W 6 - OWMPR K
0818Z	JD	FT1W DE 2HA5 R AR
0819Z	JD	C1B6 DE 2HA5 O K
		2HA5 DE C1B6 K
		C1B6 DE 2HA5 -O- 010740Z GRNC BT
		SUPPLIES NEEDED TO COMPLETE
		PROJECT BRAVO BT K
		2HA5 DE C1B6 IMI WA PROJECT K
		C1B6 DE 2HA5 WA PROJECT - BRAVO K
0822Z	JD	2HA5 DE C1B6 R AR
0824Z	JD	POWER FAILURE
0835Z	JD	POWER RESTORED
0845Z	JD	FT1W DE C1B6 R K
		C1B6 DE FT1W K
		FT1W DE C1B6 -R- 010810Z
		C1B6 DE FT1W IMI 3 TO 5 K
		FT1W DE C1B6 3 TO 5 - LMPRO ALPHD SPLOR K
0850Z	JD	C1B6 DE FT1W R AR
0859Z	JD	XY37 DE FT1W ZKJ1 ZNB LH UU K
		FT1W DE 2HA5 ZND2 INT ZNB BX K
		XY37 DE FT1W ZKJ1 ZNB WW K
		FT1W DE 2HA5 R AR
0900Z		FT1W DE C1B6 R AR
0901Z	JD	John R. Davison OFF DUTY STATION CLOSED

U.S. GOVERNMENT PRINTING OFFICE : 1964 O- [illegible] FM24-18-1-54

Figure 56. Back of operator's number sheet.

A new series of numbers should begin at 0001 hours local or Greenwich time, as directed by the commander. Whenever call signs are changed, a new series of station serial numbers is started.



FM24-18-1-55

Figure 57. Remote control operation.

126. Station Log

a. A station log, which should be maintained by radio operators at all radio stations, is provided on the reverse side of the operator's number sheet (fig. 56). This log should provide a record of operating conditions during the period of operation. Included in this log are the following:

(1) The time of opening and closing the station or circuit.
(2) Causes of delays on the circuit.
(3) Frequency adjustments and changes.
(4) Unusual occurrences, such as procedure and security violations.
(5) Natural interference or jamming.
(6) A brief description of equipment performance.

b. When opening a circuit or starting a new day, the operator will write or type his name and grade in full on the first line of the operator's sign column of the log. Where an operator is relieved or closes the circuit, he will sign immediately after the last entry made on the log. The relieving operator will write or type his name and grade in full on the next line of the log.

c. Log entries will not be erased. Changes will be made by drawing a single line through the original entry and inserting the change or changes to the lined out entry. Such changes will be initialed by the operator who makes them.

d. Maintenance of the log should not interfere with the movement of traffic.

Section XI. COMMUNICATION SECURITY

127. General

a. Communication security includes all measures taken to deny the enemy or other unauthorized personnel information that might be derived from communications.

b. Instructions governing communication security do not in themselves guarantee communication security or meet every conceivable situation, because operational requirements may limit the security measures that can be used. They do, however, make it possible to obtain a satisfactory degree of security by the sensible application of security rules.

128. Responsibility

a. Communication security is a responsibility of command. Thus, each commander must establish and supervise a positive program for communication security in his unit. This program

is normally based upon the policies of the commander, directives from higher headquarters, the communication requirements in the unit, and the tactical situation.

b. It is also the responsibility of all military personnel to develop a positive approach to communication security. This includes the application of all measures that are required to guarantee successful communication security.

129. Physical Security

a. General. Physical security is the safeguarding of communication equipment and materials from unauthorized persons. Each radio station must be physically secure, since this will enable the radio operators to use and handle information and materials without fear of disclosure to unauthorized persons.

b. Site Requirements. Radio sites should have maximum physical security.

(1) *Location.* A radio site should be readily accessible to the command.

(2) *Station construction.* A radio station should be constructed for maximum physical security with a minimum expenditure of personnel, time, and materials. Special constructions, such as fenced-in areas, barriers, and mine fields, can be used to increase physical security.

(3) *Safeguard.* The radio station should have armed guards and weapons to provide maximum resistance to forceful entry by unauthorized persons. A radio station should also have emergency destruction materials, such as incendiaries and kerosene. The requirements for these materials are greatest in the combat zone, or in areas where contact with the enemy is imminent.

(4) *Air, CBR, or nuclear attack.* A radio station should provide defense against air, CBR, or nuclear attack for both personnel and equipment.

c. Classified Materials. The following security measures should be enforced for adequate physical security of classified materials:

(1) Provide access to classified material only to persons who possess a proper security clearance and require knowledge of the material in their official duties.

(2) Maintain strict accountability for classified material, as required by regulations.

(3) Report compromise or possible compromise of classified materials.

(4) Provide proper storage for classified materials that are not being used.

(5) Transfer classified materials according to existing regulations.

(6) Initiate a destruction plan for classified equipment and materials.

130. Transmission Security

a. General. Transmission security includes all security measures used to protect transmissions from interception, traffic analysis, direction finding, and imitative deception. Since every means of transmission is subject to interception, protective measures must be taken to keep to a minimum the information obtainable by the enemy. The relative security of one means of transmission over another varies with the circumstances. Transmission security is improved by practicing the following security measures:

(1) Make transmissions as short as possible.

(2) Adhere to authorized transmission procedures. Change procedures only when so directed by proper authority.

(3) Train operators to practice circuit discipline.

(4) Provide defense against interception and direction finding.

(5) Provide defense against traffic analysis.

b. Checklist for Radio Transmission Security. A transmission security checklist for radio operators should cover the following points:

(1) Is listening silence being violated?

(2) Is unofficial conversation (chatter) being exchanged between operators?

(3) Are transmissions taking place in a directed net without permission?

(4) Is the operator's personal sign being transmitted?

(5) Are classified call signs being compromised by their association with plain language designations?

(6) Are prosigns or operating signals being used excessively?

(7) Is plain language used instead of authorized prosigns and operating signals?

(8) Are the operators using unauthorized and incorrect procedures?

(9) Are there any unnecessary transmissions, including excessive testing?

(10) Is the identification of units or individuals being disclosed in transmissions?

(11) Are calls being transmitted excessively?

(12) Are the transmitting operators sending too fast for the receiving operators to receive?

(13) Is excessive transmitting power being used?

(14) Are transmitters being tuned with the antenna connected?

(15) Is excessive time consumed in tuning, changing frequency, or adjusting equipment?

(16) If the answers to all of the above questions are negative, the radio operator is complying with transmission security measures.

Section XII. REMOTE CONTROL OPERATION

131. Application

a. Remote control equipment is used to permit keying the transmitter of a radio set while the operator is located at a point some distance from the set itself. In combat areas, a radio operator can be in a fox-hole, dugout, or other location sheltered from enemy fire, while his radio set and antenna are at a more exposed site suitable for satisfactory radio transmission.

b. Remote control equipment includes two units. One is located at the site of the radio set, and the other is located at the remote control point (fig. 57).

132. Radio-Wire Integration

Division, corps, and army communication systems usually contain both radio and telephone facilities. To provide proper communications to all mobile, airborne, and stationary units, these facilities have been interconnected by means of FM-voice radio-wire integration stations. The interconnection between a radio set at a radio-wire integration station and an area communication system switchboard is made through an AN/GSA–7 radio control set with a 5- to 10-pin adapter cable CX–7474/U and an SB–22/PT switchboard. By using the AN/GSA–7, the distance between radio and telephone equipment has been extended from 3.2 KM to 16 KM. Also, the AN/GSA–7 provides ringing facilities in both directions, thus eliminating the necessity of monitoring the circuit at either end.

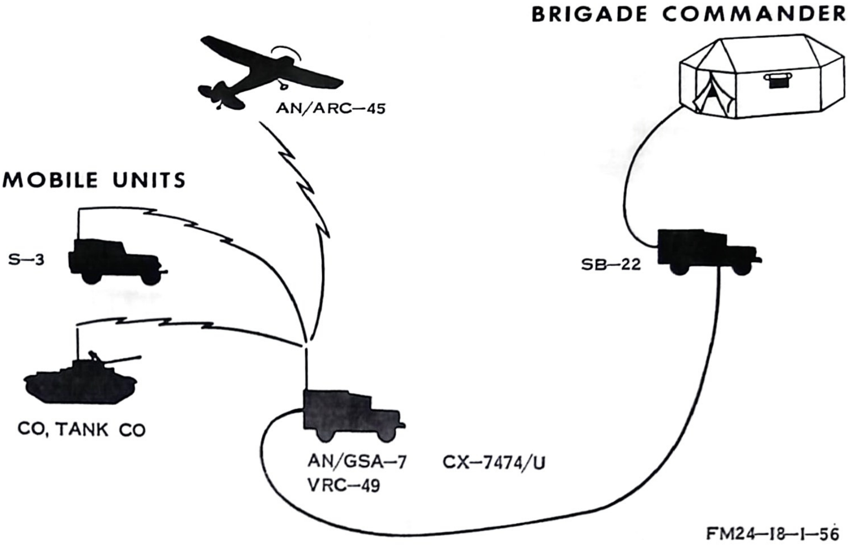


Figure 58. Type employment of radio-wire integration system.

a. At division level, a radio-wire integration station is operated at each signal center, except at division rear. Each station may be used—

(1) To establish emergency communication between mobile FM radio stations and elements connected to the division area telephone system by telephone.

(2) To establish communication between FM radio stations separated by distances that are beyond the direct operating range of their FM radio sets.

(3) By the commanding general, division staff, and other designated key personnel (fig. 58) in the division when operating from a mobile CP, to contact division elements connected to the division area communication system.

(4) For initial establishment of telephone service from the division area communication system to using units.

(5) For voice communication between mobile combat elements in the division forward area and supporting division logistic elements in the rear area.

(6) For communication between low-flying Army aircraft operating in distant parts of the division area and airstrips of flight control elements connected to the division area communication system, when direct FM radio contact cannot be maintained.

(7) For communication between forward air controllers and the air liaison officer's communication facilities, when these facilities are connected with the division area communication system.

(8) To keep commanders and staffs in contact with subordinate and higher headquarters, as required, during the displacement of CP's.

(9) To connect two switchboards and to span a break in a wire line between units.

(10) For communication during river crossings.

b. At corps level, mobile stations provide radio-wire integration facilities at corps main and corps alternate signal centers. The wire circuits from each station connect directly with the telephone central office of the army area signal center at which it is located.

c. At army level, radio-wire integration facilities are provided at each army area signal center. The army radio-wire integration stations may be used in a manner similar to the division stations (*a* above).

CHAPTER 8

RADIO OPERATION UNDER UNUSUAL CONDITIONS

Section I. INTRODUCTION

133. General

Unusual terrain and extreme climatic conditions have a significant effect upon radio communications. They will cause radio operators to deviate from the usual or normal operating techniques.

134. Personnel and Equipment

a. Radio personnel required to operate radio sets under unusual terrain and extreme climatic conditions should be given special training to prepare them to perform under those conditions. In addition, they should be given training in how to survive under adverse climatic conditions.

b. Radio sets that are to be operated under adverse conditions may require modifications and above-normal maintenance. These modification and maintenance requirements are covered in the appropriate equipment manual.

Section II. RADIO COMMUNICATION IN ARCTIC AREAS

135. General

Radio communication has certain capabilities and limitations that must be carefully considered in connection with operations in arctic regions. In spite of its limitations, radio is the normal means of communication in the arctic.

a. *Capabilities*. One of the most important advantages of radio in the polar regions is its mobility. Vehicle-mounted radios can be moved to almost any point where it is possible to install a command headquarters, and smaller radios can be manpacked to any point that is accessible only to foot troops. In addition, a radio set is smaller, lighter, and more easily installed than other means of communication required to give the same range and service.

b. Limitations. Ionospheric disturbances, known as ionospheric storms, have a definite effect on sky-wave propagation in polar regions. These storms, which are in the form of magnetic storms or auroral activity, can cause complete failure of radio communication for varying periods of time. Some frequencies may be blocked out for weeks, and the frequencies available will not always permit operators to shift to an unaffected frequency.

136. Installation

Whenever possible, radio sets for tactical operations should be installed in vehicles to reduce the problems of transportation and shelter for operating personnel. Patrols and small units that move on foot in the arctic should be provided with radio sets that can be carried on packboards or pulled in sleds.

a. Grounds. Because of permafrost, it is difficult to establish good electrical grounds in the arctic. The frozen ground makes installation of ground stakes quite difficult, and the conductivity of frozen ground is often too low to provide a good electrical conductor. Therefore, counterpoises are used extensively as grounding devices in arctic areas.

b. Antennas. In general, no serious difficulties are experienced in installing antenna equipment for arctic operations. However, installation time may be increased because of the adverse working conditions.

(1) The mast sections and antenna cables must be handled very carefully, since they become brittle at arctic temperatures.

(2) Whenever possible, antenna cables should be constructed overhead to prevent damage from heavy snow falls and frost. Nylon rope guys, if available, should be used in preference to cotton or hemp, since nylon does not readily absorb moisture and is less likely to freeze and break.

(3) Because of the poor conductivity of snow and frozen ground in the arctic, counterpoises are required in almost all radio installations. The counterpoise system should be installed high enough above the ground to insure that it will not be covered by deep snow. Deep snow on top of the system will change the antenna tuning.

(4) Antennas must be strong enough to withstand high ice and wind loading, as well as great temperature variations.

137. Operating

Radio operation in regions of snow and extreme cold presents many difficulties. However, most of these difficulties can be overcome by thorough training of personnel and the proper selection of radio equipment and frequencies.

a. Auroral Disturbances. Most operating difficulties are the result of auroral disturbances that cause excessive static, fading, or complete blackout of radio communications.

(1) Excessive static frequently accompanies or immediately follows an auroral display. This is probably caused by the excessive ionization of the ionosphere.

(2) Blackouts and fading, which may last for minutes, hours, days, or even weeks, are probably caused by changes in the density and height of the ionosphere. These changes affect the height at which the signal is refracted, thus causing the signal to return to earth at varying locations. Thus, it may be difficult or impossible to select a frequency that will insure continuous communication.

b. Frequency Selection. Low-frequency circuits (100 to 500 KC) provide the best medium for long-distance, point-to-point radio communication, because the low-frequency ground wave is not too seriously affected by auroral disturbances. Very high-frequency circuits (30 to 300 MC) are best for shorter distances (up to 50 miles (80 KM)). When using sky-wave transmission, the selection of the frequencies to be used is important. In such cases, many widely separated alternate frequencies should be provided.

138. Maintenance

Maintenance of radio equipment in extreme cold presents many difficulties. Sets must be protected from blowing snow, since snow will freeze to dials and knobs or blow into the wiring and cause shorts and grounds. Cords and cables must be handled carefully, since they may lose their flexibility in extreme cold and become brittle. All radio equipment, including power units, must be properly winterized.

a. Power Units. As the temperature goes down, it becomes increasingly difficult to operate and maintain gasoline-driven power units. They should be installed in portable heated shelters to insure that the unit will operate when required.

b. Batteries. The effect of arctic conditions on storage and dry batteries depends upon the following factors: the type and kind of battery; the load on the battery; the particular use of the

battery; and the degree of exposure to cold conditions. However, there are dry batteries that have been developed and manufactured specifically for use in arctic operations. These batteries provide more efficient operation under extreme cold conditions than normal-issue batteries. Storage and dry batteries can be stored in heated shelters or in boxes warmed by a hand warmer or similar device. Batteries that are in use may be kept warm by using a heating device inside the battery container of the equipment. Batteries used with portable equipment may be carried next to the operator's body for warmth. Batteries no longer serviceable for outdoor use may be used indoors if they are reactivated by thorough warming.

c. Shock Damage. Extensive damage can be done to vehicular radio sets by the jolting of the vehicle. Most synthetic rubber shock mounts become stiff and brittle in extreme cold and fail to cushion equipment.

d. Moisture. Condensation, which may collect inside the radio sets as a result of temperature changes, may cause failure of radio equipment. While in operation, the equipment becomes warm; it becomes cool when not in use. This change in temperature will cause condensation on contacts and wiring.

e. Winterization. When winterizing radio equipment, there may be certain parts that must be replaced because of their inability to function properly at low temperatures. Normal lubricants must be replaced with the proper arctic lubricants, because normal lubricants may solidify and cause undue wear or difficult operation.

f. Changes in Performance. The electrical characteristics of parts, such as capacitors and resistors, may change under conditions of extreme cold.

g. Personnel. Additional maintenance personnel will be needed to meet increased maintenance requirements in the arctic. However, this number can be kept to a minimum by training radio operators in maintenance techniques. Since the lack of transportation and the employment of small independent forces often preclude the use of normal maintenance and repair channels, personnel must be assigned to the lower echelons of command to provide maintenance support. Whenever possible, maintenance personnel should accompany task forces to perform *on-the-spot* maintenance of radio equipment.

h. Shelter and Heat. If possible, heated shelters should be provided to protect maintenance equipment and personnel from extreme cold. Repair vans, in excess of normal allowances, may

be required to furnish shelter and heat, and to provide the mobility necessary in fast-moving tactical situations.

i. Microphones and Transmitters. Moisture from the breath may freeze on the buttons and perforated cover plates of microphones, thereby rendering the microphones inoperative. Standard microphone covers should be used to prevent this. If standard covers are not available, a suitable cover can be improvised from thin rubber or cellophane membranes, or from cloth, such as rayon or nylon fabric.

j. Mechanical Malfunctioning. The various metals in radio equipment contract differently in extreme cold. This may cause binding or locking of mechanical trains. Plugs, jacks, keys, shafts, bearings, dials, and switches are subject to malfunctioning because of this difference in the amount of contraction.

k. Breathing and Sweating.

(1) A radio set will generate heat when in operation. As the air inside the radio set cools, it contracts and draws cold air into the equipment from the outside. This is called *breathing.* When a radio set breathes, and the hot equipment comes in contact with subzero air, the glass, plastic, and ceramic parts of the set may cool too rapidly and break.

(2) When cold equipment is brought suddenly into contact with warm air, moisture will condense on the equipment parts. This is called *sweating.* Before cold equipment is brought into a heated room or shelter, it should be wrapped in a blanket or parka to insure that it will warm gradually. Equipment must be thoroughly dry before it is taken into the cold air, or the moisture will freeze.

Section III. RADIO COMMUNICATION IN JUNGLE AREAS

139. General

Radio communication is seriously limited by dense jungle growth.

a. The operating range of short-range, tactical radio sets in the jungle varies from 10 to 60 percent of the range for open or lightly wooded areas.

b. Because of poor transportation facilities, large and powerful radio sets will usually be used only in rear areas, or at sites immediately adjacent to roads, trails, paths, or navigable water-

ways, depending upon the density and moisture content of the vegetation.

c. Field radio sets used in the jungle must be given great care because of the damage resulting from heat, moisture, fungi, or insects.

140. Long-Range Communication

Long-range radio communication in the jungle is possible only when the antenna is clear of surrounding jungle growth. When antennas are so sited, long-range communication is similar to that for any other military operation.

141. Line-of-Sight Communication

Line-of-sight communication is used when dense jungle growth makes HF ground wave transmission impossible.

142. Installation

a. Antennas. A radio antenna must be correctly sited for maximum efficiency. However, military considerations may require the use of other than the best antenna sites. The following rules are useful guides when siting radio antennas and for improving radio communication in the jungle:

(1) Antennas should be located on hills overlooking the surrounding terrain and jungle growth.

(2) Antennas should be located in clearings on the edge farthest from the distant station. The clearing should extend at least 100 yards from the antenna in the direction of the distant station.

(3) Directional antennas should be oriented in straight-line paths. When intervening jungle growth or terrain masks the straight-line transmission path, the antenna can be oriented slightly off-course, particularly when the off-set course path is unobstructed.

(4) Antennas should be located as high as possible when the antenna site is located directly behind an intervening terrain mask. If feasible, tie the radio set to the top of a tree and operate it from that location by remote control. Slight tilting of an antenna away from the direction of the distant station also will help to breach an obstacle.

(5) Antennas should not be located in narrow valleys or between ridges or stretches of high jungle growth.

(6) Antenna cables and connectors should be kept off the ground to lessen the effects of moisture, fungi, and insects. This also applies to all power and telephone cables.

(7) Complete antenna systems, such as ground planes and dipoles, are more effective than fractional wave-length whip antennas.

(8) Vegetation, particularly when wet, will act much like vertically polarized antennas and absorb much of a vertically polarized radio signal. Therefore, horizontally polarized antennas must be used in preference to vertically polarized antennas.

b. Sites. Jungle growth must be cleared from antenna sites. If an antenna touches foliage, the signal will be grounded, especially during the rainy season.

c. Shelter. When mobile shelters are not available, tents or shacks should be erected to house radio stations. Floors should be built in these shelters to hold equipment off the damp ground and away from moisture, fungi, and insects. These shelters should be so constructed that air will circulate about the installed equipment.

143. Operation

Tropical rains, heat, fungi, and insects combine to produce major problems in the operation of radio equipment. As a result, the effective operation of radios in the jungle depends to a great extent on the training, resourcefulness, and perseverance of the individual operators.

144. Maintenance

Because of moisture and fungus growth, maintenance of radio sets in tropical climates is more difficult than under temperate climatic conditions. The high relative humidity causes condensation to form on the equipment. This is especially true when the temperature of the equipment becomes lower than the surrounding air. To minimize this condition, keep the sets turned on or place lighted electric bulbs near the equipment.

Section IV. RADIO COMMUNICATION IN DESERT AREAS

145. General

Radio is usually the primary means of communication for military operations in the desert. It can be employed effectively

in desert climate and terrain, and it furnishes the highly mobile means of communication demanded by widely dispersed forces operating in a fluid situation.

146. Electrical Grounds

Desert terrain provides poor electrical grounds. Unless corrective action is taken, the communication range of radios will be greatly reduced. The adverse effects of poor electrical grounds may be overcome through the use of a counterpoise.

147. Antennas

a. For the best results in the desert, radio antennas should be located on high ground immediately overlooking the surrounding terrain. At frequencies from 1 to 20 MC, the best range can be obtained when antennas are located near oases or subterranean water. These antennas should be equipped with counterpoises.

b. Transmitters using whip antennas in desert terrain will lose one-fifth to one-third their normal range. For this reason, it is important to use complete antenna systems, such as horizontal dipoles and vertical antennas with adequate counterpoises.

148. Operation and Maintenance

a. In the operation of radio sets in desert areas, the maintenance problem is increased by the large amounts of sand, dust, or dirt that enter the equipment. Sets equipped with servomechanisms are particularly affected. To reduce maintenance downtime, keep the sets in their dustproof containers as much as possible.

b. Preventive maintenance checks should be made frequently. Particular attention should be given to the lubrication of equipment, since excessive amounts of dust, sand, or dirt coming into contact with oil and grease will produce grit that can damage the equipment.

Section V. RADIO COMMUNICATION IN MOUNTAINOUS AREAS

149. Limitations

The installation, operation, and maintenance of radio equipment in mountainous areas is difficult. Terrain masks and extreme and rapid changes in weather and temperature often interfere with continuous communication. There is an additional

problem in keeping radio sets and dry batteries operative and free of condensation.

150. Installation

a. Directional antennas should be oriented at small angles off the straight-line course when high mountains lie in the straight-line transmission path.

b. Valleys and gaps should be used for transmission paths between mountains.

c. When siting a radio station directly behind a high, intervening mountain mask, the antennas should be located on the highest ground possible.

d. The antenna cables should be elevated above the ground to insure that they will not be buried in the snow or frozen to the ground. This applies also to all power and telephone cables.

e. The antenna joints and cable connectors should be kept out of snow and water.

f. During the winter, the metal mast sections and antenna cables should be handled carefully, since they become brittle at low temperatures.

g. When the ground is frozen, counterpoises should be installed for antennas.

h. Antennas should be located on the top or the forward slope of a mountain. If possible, they should be high enough to provide line-of-sight paths.

i. Complete antenna systems, such as ground-planes or dipoles, are more effective than fractional wavelength whip antennas, especially when operating over snow or frozen ground.

j. The use of relay stations in mountainous areas provides communication beyond the range of HF ground waves.

(1) Radio relay terminals should be located on high peaks, thus allowing line-of-sight transmission.

(2) To solve special communications problems, aircraft may be used to relay messages between radio stations that cannot communicate with each other.

(3) Relay stations located at critical points will provide radio communications between terminal stations. This will reduce the length of each radio link and the noise-to-signal ratio. However, the use of relay stations will increase the total number of sets used. These additional sets add to the transportation difficulties and produce a requirement for an increased number of specialized technicians to install, operate, maintain, and repair the radio equipment.

CHAPTER 9

RADIO FREQUENCY ALLOCATION AND ASSIGNMENT

Section I. CONTROL OF RADIO OPERATING FREQUENCIES

151. Interference

If all radio sets in a division attempted to operate on the same frequency, or on frequencies selected at random by operating personnel, radio communication would become extremely impractical if not impossible. When two or more radio transmitters are operated at the same time on the same frequency channel, a jumble of distorted and unintelligible signals is received at the receiving station. This type of interference can occur easily between net stations that are required to operate on the same frequency. The NCS normally can minimize such interference by regulating transmissions within the net. Since some radio waves travel for many miles in all directions, unintentional interference to other nets can easily occur unless the transmissions of all stations are governed by strict controls and operating frequencies are selected carefully.

152. Spectrum Utilization

The ideal arrangement for providing interference-free radio communication is to assign a different operating frequency to each radio net. Unfortunately, the number of available radio channels is limited. Only a small portion of the radio frequency spectrum is suitable for tactical radio communication. The usable portion is further limited because each radio channel occupies a *band* of frequencies rather than a single frequency. A CW radio or radio teletypewriter signal occupies approximately 1 KC of the spectrum, an AM voice channel uses 10 KC, an FM voice channel occupies 50 to 100 KC, and a television channel requires 6,000 KC. In addition to the spectrum space actually occupied by the radio signal, additional separation between adjacent radio channels must be provided to minimize the possibility of mutual interference.

153. Tactical Conditions

In addition to the technical considerations that make the selection and control of radio channels necessary, tactical conditions may also require the use of controls. For these reasons a schedule of operating frequencies is given to each station. Alternate frequencies are often made available to be used when the original frequency is unreadable because of natural interference or enemy jamming. For security reasons it is sometimes necessary to assign a new frequency every day.

Section II. ASSIGNMENT OF RADIO FREQUENCIES

154. General Procedure

To reduce the amount of confusion that comes from a lack of strict frequency control, the army signal officer exercises control of all frequency assignments in the theater. He assigns a specific frequency channel to each net under his direct control. Each major subordinate army headquarters then is allotted a group, or list, of frequencies from which specific assignments to radio nets under direct control of the subordinate unit may be made. This process of allotting lists of frequencies continues down through corps headquarters to division headquarters. In general, the division signal officer (DSO) assigns specific frequencies to many of the subordinate units within the division. However, the DSO may suballot lists of FM channels to each infantry battalion which, in turn, may assign a number of channels to be used within each company. Since the distance range of combat radio sets is relatively short, duplicate frequencies can often be assigned to companies separated by a distance greater than one mile. When these assignments are completed, each radio net in the theater of operations is assigned an operating frequency. Radio frequency assignments are published in the SOI of the assigning headquarters.

155. Basic Considerations

a. An ideal frequency assignment is one that permits each net to operate on its assigned frequency without causing interference to, or getting interference from, another net. The first step in achieving this is to assign different frequencies to all nets operating within interference range of each other. This is facilitated by the system of allotting selected lists of frequencies to each assigning headquarters to keep duplication of assignments to a minimum.

b. The radio frequencies assigned to the different nets in a division must be taken from a list made available by army. These lists give authorized frequencies and call signs for use by the designated division.

c. Appropriate frequencies and call signs are assigned, from the allotted list, to each radio station and net within the division. These assignments are published in the division SOI.

d. When making frequency assignments to specific radio nets, consideration is given to the compatible frequency ranges of the various radio sets that may be used in the same net. Therefore, no frequency outside of this compatible range is assigned to the net, even though the frequency is listed as available.

156. Frequency Band Separations

The assignment of a different frequency to each net is not all that is required to insure interference-free operations. Radio signals may occupy less than 1 KC or as much as several hundred kilocycles on a receiver tuning dial. For this reason, adequate separation must be provided between adjacent radio frequency assignments.

a. Type of Emission (CW, Voice, or RATT). In general, the separation will be approximately the same for CW and RATT. A greater separation is required for voice communications.

b. Type of Modulation (AM or FM). Tactical FM radio equipment requires a 50-KC band for each channel (older sets require 100-KC channels), whereas AM equipment requires a 10-KC band for each channel. The separation between adjacent FM channels must be proportionately greater than the separation between adjacent AM channels.

c. Frequency Stability and Accuracy of Transmitter. The calibration of most field radio transmitters is not accurate. In addition, the frequency generated by the oscillator in the transmitter often has a tendency to change or drift. To minimize inefficiency caused by off-frequency operation, most field radio stations are required to maintain an accuracy of 0.01 percent of the assigned frequency. For example, an assignment of 4,000 KC (4,000,000 cycles), with a tolerance of 0.01 percent, permits the transmitter frequency to vary 400 cycles above or below the assigned frequency. This factor obviously affects the amount of separation between adjacent operating channels.

d. Power Output of Transmitter. The transmission distance and the interference capability of a transmitter are directly related to its rated power output. A high-powered transmitter can

block local radio receivers completely if a sufficient separation in operating frequencies is not provided. For this reason, the use of minimum power output consistent with satisfactory communication is often stipulated in the SOP.

e. Distance Separation Between Different Nets. A radio signal, when received at a distant station, may occupy only a few kilocycles on the receiver dial. When received on a nearby receiver, the same signal will normally occupy a much broader band of frequencies. Since adjacent channel interference occurs more readily when stations are located close together, a relatively large separation must be provided between operating frequencies assigned to different net stations located at the same command post.

157. General Guide for Initial Frequency Assignments

a. The various factors outlined in the preceding paragraph indicate that the amount of separation between operating frequencies can vary. To conserve the usable frequency spectrum it is important to use minimum separations. Satisfactory radio frequency assignments can be made by referring to the Short Distance Ground and Sky-Wave Prediction Charts, which are published every 3 months.

b. Initial frequency assignments may prove to be unsatisfactory and adjustments may be required. For example, changes in preliminary planning may be required when frequencies used by the enemy, friendly governments, or commercial agencies cause interference in communication systems. Then, too, interference may be caused by harmonic frequencies of these sources, as well as those of our own transmitters. Harmonics are the frequencies that are multiples of the assigned, or fundamental frequency. For example, an assigned frequency of 4,000 KC may radiate interfering harmonic signals at 8,000 KC, 12,000 KC, 16,000 KC, etc. These multiples of the fundamental frequency are known respectively as the second, third, and fourth harmonics.

c. There may be times also when it is impossible to provide radio frequencies that permit all radio nets of a division to operate free from interference. In such cases it is necessary to silence a portion of the nets, giving preference to nets and stations with highest priorities.

CHAPTER 10

JAMMING

Section I. INTRODUCTION

158. General

a. Reception of radio signals is often prevented by the interference of unwanted signals in the receiver. Such interference may be intentional (from unfriendly sources) or unintentional (from friendly sources). Intentional interference is called *jamming.*

b. Radio jamming is the transmission of radio waves to obscure or obliterate information normally received by radio receiving equipment. Jamming is used to disrupt radio communication, and to surprise, confuse, and mislead radio operators.

c. All radio frequencies are vulnerable to jamming, and the enemy will jam radio reception whenever it is advantageous. To accomplish this, he will select the frequency to be jammed, tune a transmitter to that frequency, and transmit a strong signal to prevent reception of the desired signal.

159. Basic Types of Radio Jamming

There are two basic types of radio jamming—spot jamming and barrage jamming.

a. Spot Jamming. This is the transmission of a narrow-band signal to interfere with a specific frequency or channel.

b. Barrage Jamming. This is the transmission of a wide-band signal to interfere with as many channels as possible. Barrage jamming can also be produced by operating several narrow-band transmitters simultaneously on adjacent frequencies or channels.

160. Distinction Between Interfering Signals

There are two sources of interfering signals—external and internal. If the disturbance heard in the receiver can be elim-

inated or substantially reduced by grounding or disconnecting the receiver antenna, it can be assumed that the trouble is being caused by some external source. If the disturbance remains unchanged when the antenna is disconnected or grounded, the disturbance is caused by the receiver. This is an indication that the set is not functioning properly. If interference is caused by some external source, a further check must be made to determine whether the cause is enemy jamming or accidental interference.

161. Distinction Between Jamming and Accidental Interference

a. Unintentional interference from friendly radio and radar stations is called *accidental* interference. This interference can occur when the harmonics of a transmitted radio wave interfere with other radio frequencies.

b. Spot jamming may be distinguished from accidental interference by tuning the receiver a few kilocycles above or below the normal operating frequency. If the intensity of the interfering signal drops sharply as the receiver is tuned away from the operating frequency, it can be assumed that the interfering signal is a result of spot jamming.

c. It is difficult to distinguish barrage jamming from accidental interference, since both types of disturbance may extend over all or most of the receiver's tuning range. Accidental interference, however, usually travels only a short distance from its source, and a search of the immediate area may reveal that the cause of the disturbance is an electric fan, a razor, or a similar electrical device. The use of a small portable receiver in the station area often can be of aid in making this identification. If the received signal shows noticeable variations in signal strength as the receiver is moved around the station area, the disturbance is probably accidental interference of local origin; conversely, little or no variation in signal strength indicates that the interfering signal may be enemy jamming. Accidental interference should be reported immediately and eliminated.

d. Accidental interference may also be caused by receiver blocking, modulation splatter (over modulation of an AM transmitter), clicks, and spurious radiations generated by a nearby friendly transmitter. These types of interference should be reported by the radio operator to his supervisor, so that immediate corrective action can be taken.

e. The existence of unidentifiable interfering signals should be

reported to higher headquarters immediately. This reporting procedure often enables the headquarters to determine whether or not unfriendly jamming is present. The headquarters can make this determination by correlating reports from several units operating on various frequencies within a particular portion of the spectrum.

162. Identification of Jamming Signals

Systematic identification of signal characteristics of a jamming signal followed by the proper antijamming procedure saves time. It can be assumed that an unfriendly force is constantly striving to perfect and use new and more confusing forms of jamming signals. The operator must expect combinations of the basic types of modulation, totally new types, and a variety of voice signals, such as singing, music, and laughter. These voice signals provide effective jamming signals and often have strong psychological effects.

a. It is quite difficult for a radio operator to distinguish jamming from other types of interference. Therefore, he should become familiar with the characteristic sounds of jamming signals during his training period.

b. Jamming signals are classified as continuous-wave signals and modulated signals.

163. CW Jamming Signals

a. Random Keyed CW. This signal is an unmodulated carrier keyed at random. It is used primarily to jam radio teletypewriter and radio-facsimile circuits, but it may be used to jam CW circuits.

b. Keyed CW. Signals of this type are similar to those of the random keyed CW. In keyed CW, however, actual Morse code characters are transmitted at the same rate, or slightly faster, than the signal being jammed. It is used against radiotelegraph circuits.

164. Modulated Jamming Signals

a. Spark. The spark jamming signal is one of the simplest, most effective, and most easily produced of all jamming signals. To the operator, this type of jamming signal appears to be a burst of noise of short duration and high intensity. It is repeated at a rapid rate and is much louder than the desired signal. The time required for the receiver, the earphones, and the human ear to recover after each jamming signal makes these signals, al-

though of short duration, effective against all types of radio communication. In addition, the spark signal has a broad-band characteristic that enables one jammer to cover a number of communication channels.

b. Sweep-Through. In this jamming technique, a carrier signal is swept or moved back and forth across a frequency band at a rapid rate. The sweep-through jamming signal, which is effective over a broad range of frequencies, produces a sound that is similar to that of a conventional aircraft engine. When used with a high-speed sweep, the signal is effective against all types of voice-modulated transmissions. With a low-speed sweep, it is effective against automatic radio teletypewriter and radiotelegraph transmissions.

c. Stepped Tones. This signal, which is more commonly called *bagpipes* because of the sound of the signal, consists of a number of separate audio tones (usually three or five). These tones are transmitted in increasing pitch and then in decreasing pitch. When repeated over and over again, they produce an audible effect that resembles the sound of Scottish bagpipes. Needless to say, these tones have a demoralizing effect on radio operators. This type of jamming signal is usually used against single-channel voice circuits that are either amplitude- or frequency-modulated.

d. Random Noise. This signal produces a synthetic radio noise—noise that is random both in amplitude and frequency. Since it has no periodically recurring frequency, it cannot be eleminated without also removing the desired signal. Random noise is considered to be one of the better and more dangerous types of modulation jamming, because the operator may mistake it for receiver or atmospheric noise and fail to take antijamming action. Noise jamming is effective against all types of radio communications.

e. Random Keyed Modulated CW. This jamming signal is produced by keying a CW signal at random and modulating this keyed signal with spark noise. This type jamming is particularly effective against voice channels.

f. Rotary. The rotary jamming signal is produced by a low-pitched, slowly varying audio frequency. This signal, which sounds like grunting, is used to jam voice-modulated circuits.

g. Gulls. The gull jamming signal is generated by a quick rise and slow fall of a variable audio frequency. The sound produced is similar to the cry of a sea gull. This jamming signal produces only a nuisance effect on voice-modulated circuits.

h. Pulse. The pulse jamming signal resembles the monotonous rumble of high-speed rotating machinery. It produces a nuisance effect on voice-modulated circuits.

i. Tone. The tone jamming signal is a single frequency of unvarying tone that has only a limited effect on radio communications. It is used primarily to jam manually keyed CW and voice-modulated circuits, but it may also be used to jam radio carrier circuits.

j. Wobbler. The wobbler jamming signal is a single frequency modulated by a low and slowly varying tone. The result is a howling sound that produces a nuisance effect against voice-modulated radio circuits.

Section II. PREVENTIVE MEASURES AGAINST JAMMING

165. Precautionary Measures

If it is determined that there is a need to set up precautionary measures against jamming, preliminary action can be taken in engineering the circuits and nets, in training radio operators, and in determining the source of the jamming.

a. Circuit or Net Engineering. To combat jamming, it is necessary to—

(1) Provide circuits with a stronger received signal than normally would be required.

(2) Reduce the length of some circuits. Extra-long circuits are not dependable.

(3) Provide alternating routing or alternate channels of radio communication.

(4) Arrange nets so that satellite stations can communicate with each other, as well as with the control station.

(5) Insure that all radio equipment will be maintained in good condition and will be well-aligned.

(6) Provide high-powered standby transmitters, or RF amplifiers, to overcome jamming signals.

b. Training. All operators should be trained in reception through jamming, as well as in the recognition of jamming. In addition, they should be directed to refer to the equipment manual of the radio equipment being used for antijamming procedures.

c. Source Location. If a direction-finding organization is available, it can be used to locate the jamming source. Then, action can be taken to eliminate the jamming problem. If sky-wave

jamming is involved, high-angle direction-finding equipment is required.

166. Remedial Measures

a. Practice. Radio operators should practice reception through jamming. Well-trained personnel can often read the desired signal through the jamming signal.

b. Recognition. Immediate recognition of intentional jamming is of prime importance. Prompt reporting of jamming to the direction-finding organization for location of the source and coordinated action against the source may discourage future jamming.

c. Receiver Alignment. Properly aligned radio receivers are often capable of separating the desired signal from the jamming signal. Maintenance personnel should refer to the equipment manual of the specific radio receiver in use and then realign the set for the greatest selectivity and the narrowest band pass possible.

d. Antenna Directivity. Discrimination between a desired signal and a jamming signal may be effected by changing the location or the directivity of an antenna (if the antenna is movable).

e. Additional Power. More transmitter power may increase the signal strength at the receiver to the point where the desired signal overrides the jamming signal. If the circuit being jammed is an AM voice circuit, overmodulation of the transmitter may provide additional intelligibility through a narrow jamming signal, thereby making the circuit operable. If the transmitting operator then speaks slowly and distinctly, the receiving operator may be able to copy the message.

f. Change to CW. If CW operators are available, CW may be substituted for voice or radio teletypewriter transmission. Transmission of CW at slow speed increases the intelligibility through jamming.

g. Service Modification. In multichannel systems, different channels may be tried, and the audio transmitting gain on each channel may be slightly increased. If none of the channels are satisfactory, fewer total channels may be used, thereby raising the relative audio power of each individual channel.

h. Relay. Messages may be relayed over alternate routes.

i. Frequency Change. The use of a different frequency may provide a usable desired signal.

Section III. OPERATIONS DURING JAMMING

167. General

It is imperative that radio operators continue to operate their radio sets during enemy jamming attacks. Although not all antijamming measures are the sole responsibility of the radio operator, he is directly responsible for continued operation.

a. The ability of a radio operator to work effectively through jamming depends upon his ability and skill. A skillful radio operator can learn to read a desired signal through all but the most severe cases of jamming. To become skillful, he must practice the receptoin of signals through all forms of jamming.

b. Different types of jamming require different antijamming techniques. Techniques have been developed to combat the effects of almost all types of jamming.

168. Station Procedures

a. The siting and orientation of an antenna are important factors in reducing the effects of jamming. In VHF and UHF systems, for example, the antenna should be so located that hills, buildings, or other obstructions lie between the antenna and the enemy jamming station.

b. In many instances, the use of a directional antenna will reduce the effects of enemy jamming.

c. The radio station must operate at maximum efficiency to effectively combat enemy jamming. Malfunctions of equipment must be corrected promptly.

d. Radio operators should be directed to transmit only when absolutely necessary, because radio transmissions are easily intercepted by the enemy. The less the enemy knows about our radio station, the less effective will be his jamming efforts.

e. A dummy antenna (para 66) should be usde during transmitter tuneups to reduce the possibility of enemy interception of our radio transmissions.

f. Initially, radio transmitters should be operated with the least amount of radiated power necessary for satisfactory communication. Later, it may be necessary to increase the power to override an enemy jamming signal.

g. Radio operators should be trained to transmit clear, crisp code characters. This will aid the receiving operators to read the desired signal through an enemy jamming signal.

169. Transmission Speed

A reduction in the speed of CW and voice transmissions will be helpful to the receiving operator during an enemy jamming attack. However, operators should not reduce speed immediately, since such a reduction might indicate to the enemy that jamming is effective. Deceiving the enemy as to the effectiveness of his jamming will sometimes discourage him from further jamming efforts.

170. Keeping Equipment in Operation

Radio stations must continue to operate even though their circuits are blanketed by jamming signals. A shutdown would indicate to the enemy that his jamming efforts have been successful. If the jammed stations continue operation, antijamming action can be taken while the enemy is busy jamming. Thus, other friendly stations, operating on different frequencies, will be protected from possible jamming action.

171. Receiver Control Techniques

Receiver controls can be used to reduce the effectiveness of enemy jamming. Thus, practice in the use of receiver controls, under simulated jamming conditions, will develop the operator skills required to improve reception during actual jamming attacks.

a. Tuning. The operator should carefully tune the radio receiver to the incoming signal, rather than to a dial marking.

b. Gain Control. The effects of spark, sweep-through, and frequency-modulated jamming can be reduced by skillful use of the gain control. Frequency-modulated jamming signals may be effectively reduced in an amplitude-modulated receiver by increasing the gain control above normal. The effects of noise, bagpipes, or other slowly varying tone jamming signals may be reduced by adjusting the gain control below normal.

c. Beat-Frequency Oscillator. In CW operation, the beat-frequency oscillator (BFO) control can be adjusted to reduce the effects of CW jamming signals that are slightly above or below the operating frequency. By varying the BFO control, the tones of the desired signal and the jamming signal are varied so that the desired signal may be distinguished from the jamming signal.

d. Crystal Filter. Some radio receivers have an adjustable crystal filter (or other type of filter) that may be used to reduce the effectiveness of a jamming signal. This control is effective in reducing jamming signals slightly above or below the frequency

of the desired signal. By varying the filter control, it may be possible to reduce the effect of, or even eliminate, the jamming signal.

Section IV. REPORTING JAMMING

172. Importance of Reports

Prompt, accurate, and complete reporting of enemy jamming is important, since an enemy jamming attack is usually part of a well-organized plan and frequently precedes important tactical maneuvers. The reports from the individual radio operators, which frequently provide intelligence on the extent and importance of enemy action, are normally correlated at division or corps headquarters by electronic warfare personnel. Properly correlated jamming information may serve as a warning of impending enemy action in a sector or on a broad front.

173. Initial Report

The radio operator must report jamming immediately to his communication supervisor. Any attempted or successful enemy deception should also be reported. The communication supervisor, in turn, will send the report to higher headquarters for action. Jamming information should be recorded on the Operator's Log (DA Form 11–53) to facilitate reporting. Information on jamming should be reported in the following order:

a. Frequency or channel being jammed, including the width of the jamming signal, if known.

b. Type of jamming signal.

c. Time and duration of jamming, including any repetition.

d. Signal strength of jamming signal and effect on radio communications. (Signal strength of jamming is reported as strong, medium or weak.)

e. Unit, name, and rank of operator making the report.

174. Detailed Report

A detailed report of the jamming is prepared by the officer in charge of the radio station as soon as practical after the jamming starts. The officer in charge of the radio station forwards this report to his commanding officer, who then forwards the report through channels as required by local instructions.

Section V. JAMMING CHECKLISTS

175. Commanders and Staff

Each unit commander and his staff should—

a. Reduce the use of radio messages to an absolute minimum.

b. Preplan all operations, if possible, and use brevity codes to effect plans and directives.

c. Keep messages as short as possible.

d. Stress radio discipline and security.

e. Destroy enemy jamming stations, when possible.

f. Always inform the next higher headquarters of enemy jamming.

176. Signal and Communications Officers

Each signal or communication officer should—

a. Use the radio only when necessary.

b. Train radio operators to readjust equipment and continue copying through jamming.

c. Enforce radio discipline and security to the maximum.

d. Require authentication of all transmissions.

e. Site radio stations and antennas to evade enemy jamming.

f. Always include alternate call signs and frequencies in the SOI, and include prearranged plans for their use.

g. Always report enemy jamming to the commanding officer and his staff.

177. Radio Operators

Each radio operator should—

a. Learn to recognize enemy jamming and report details to the officer in charge of the radio station.

b. Learn to readjust the set to minimize the effects of enemy jamming.

c. Operate with minimum power until jammed—then, increase the power.

d. Shift to alternate frequencies and call signs as directed.

e. Authenticate all transmissions.

f. Use a dummy antenna, when one is provided, to tune the transmitter.

g. KEEP OFF THE AIR as much as possible. Transmit only when absolutely necessary.

h. Observe radio discipline at all times.

i. Keep transmissions as short as possible.

j. Keep calm, keep trying, and keep operating when the circuit is jammed.

CHAPTER 11

MAINTENANCE OPERATIONS

Section I. INTRODUCTION

178. General

a. Maintenance operations are assigned to specific levels of command in accordance with the primary mission, characteristics, and mobility of the level involved, and the economical distribution of resources.

b. Repair parts allowances and initial guide quantities are selected and allocated to organization, direct support, general support, and depot maintenance organizations in accordance with the provisions of AR 700–18. The supply of repair parts below Army field depot/installation level will be accomplished by maintenance support organizations.

179. Categories of Maintenance

There are four broad categories of maintenance (fig. 59) that have been defined by the Department of Defense for all services. They facilitate the assignment of maintenance missions and responsibilities within the Department of Defense.

a. Organizational Maintenance. Organizational maintenance is that maintenance normally authorized for, performed by, and the responsibility of a using organization on equipment in its possession. This maintenance consists of functions and repairs within the capabilities of authorized personnel and is performed using organizational tools and test equipment. Maintenance exceeding the authorized scope of maintenance may be performed when authorized by the next higher maintenance support commanders.

b. Direct Support Maintenance. Direct support maintenance is that maintenance normally authorized and performed by mobile repair teams from designated maintenance activities in direct support of using organizations. This category of maintenance is limited to the repair of end items or unserviceable assemblies in support of using organizations on a return-to-user basis.

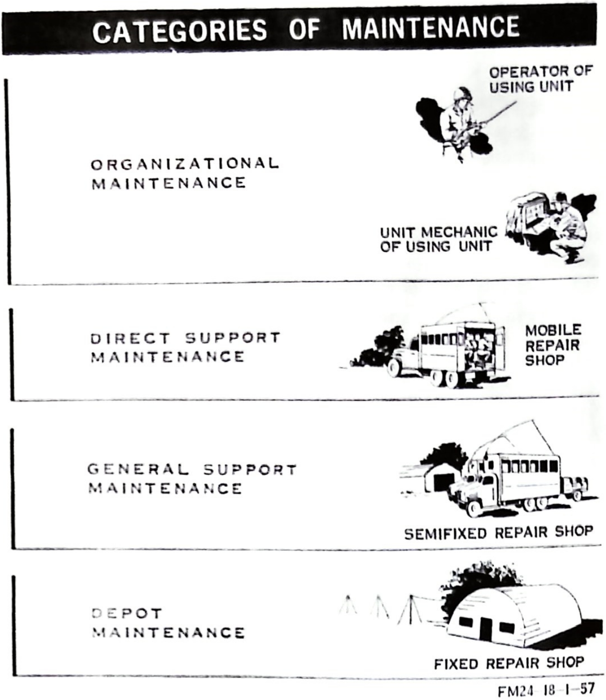


Figure 59. Categories of maintenance.

c. *General Support Maintenance.* General support maintenance is that maintenance authorized and performed in semifixed or permanent shops by designated organizations in support of the Army supply system. Normally, general support maintenance organizations will repair or overhaul materiel to required maintenance standards in a ready-to-issue condition based upon applicable supported Army area supply requirements.

d. *Depot Maintenance.* Depot maintenance activities, through overhaul of economically repairable materiel, augment the procurement program in satisfying overall Army requirements and, when required, provide for repair of materiel beyond the capability of general support maintenance organizations.

Section II. PREVENTIVE MAINTENANCE

180. General

Preventive maintenance is the systematic care, inspection, and servicing of equipment to maintain it in serviceable condition and prevent breakdowns. It is accomplished by equipment operators and organizational maintenance personnel.

a. Radio operators, who are highly trained in operating techniques, perform only those simple routine maintenance operations that can be performed by men with a limited technical background. Each appropriate technical manual covers these preventive maintenance measures in an operational checklist.

b. Organizational maintenance personnel provide maintenance backup support to the operator, and are responsible for organizational maintenance that requires limited technical training. Each appropriate technical manual contains equipment performance checklists and other organizational maintenance information.

181. Responsibility

Commanders are responsible for insuring that personnel under their command comply with procedures and instructions dealing with preventive maintenance and that they fill out the required maintenance records as provided by TM 38–750.

182. Preventive Maintenance Services

a. Daily Service. Preventive maintenance services are performed by the radio operator each day the equipment is operated. The equipment is inspected and serviced in accordance with procedures outlined in the applicable equipment technical manual. Deficiencies and shortcomings that are not corrected by the operator, or that are corrected by replacement of parts, are recorded on an appropriate maintenance form (TM 38–750).

b. Periodic Services. These inspections and services, prescribed by appropriate technical manuals, are performed by organizational maintenance personnel. At the time of service, organizational maintenance personnel, assisted by the operator, systematically inspect and service the equipment. All deficiencies and shortcomings, as well as the corrective action taken for each, are recorded on an appropriate maintenance form (TM 38–750). If repairs by a higher category of maintenance are required, an appropriate maintenance form will be prepared and forwarded with the equipment to the supporting maintenance activity.

183. Electric Shock Hazards and Safety Precautions

a. General. High voltages may be required in the operation of radio sets. Therefore, radio operators and maintenance personnel should first become familiar with the equipment manual before operating the equipment.

***Warning:* DEATH ON CONTACT may result if operating and maintenance personnel fail to observe safety precautions.**

b. Precautions. Whenever radio sets use high voltages, the radio operator should observe the following operation and maintenance precautions:

(1) Be careful not to contact high-voltage or power connections.

(2) Avoid contact with transmission lines and antennas that have radio frequency voltages.

(3) When working inside radio sets, be sure that the power source is disconnected and that high-voltage capacitors are discharged.

(4) Check the equipment manual for a list of components that contain high voltages.

Section III. OPERATOR MAINTENANCE

184. Maintenance Training

Maintenance of radio equipment and accessories is of sufficient importance to warrant training of all operators in certain minimum maintenance procedures and in the reporting of deficiencies and shortcomings that they are not authorized to correct. This training must be conducted simultaneously with training in operating procedures and must be covered thoroughly. The maintenance procedures authorized to be performed by operators should be taught as part of the operating procedures.

185. Elements of Operator Maintenance

The elements of operator maintenance can be broken down as follows:

a. Maintenance before operation (physical condition checks).

b. Maintenance during operation (constant check of the performance of the set and observation of unusual performance).

c. Maintenance after operation (inspection and performance checks to be sure that the set will be ready to operate when needed).

186. Maintenance Before Operation

Before operating any radio set, the operator should—

a. Check all cables and connectors.

(1) Be sure that all connectors are in good condition and tightly connected to the proper receptacles.

(2) Be sure that all cables are in good condition, clean, dry, and placed where they will not be damaged during normal operation.

(3) Wipe off any grease, oil, moisture, or other foreign matter from cables and connectors.

(4) Be sure that cables are not stretched taut, have no kinks or tight bends (especially near the connectors), are not pulled tight against sharp edges or corners of equipment cases, are not under pressure caused by items placed upon them or leaned against them, not subjected to excessive heat or direct sunlight.

b. Check all controls, switches, and knobs.

(1) Be sure that all switches and controls move through their required motion without application of excessive force.

(2) Be sure that knobs are securely attached to the shafts of switches and controls.

(3) Be sure that indexed knobs are oriented on their shafts so that they indicate the proper setting at each position.

(4) Be sure that all switches and controls stop at their limits, unless they are intended to rotate continuously.

(5) Replace missing knobs (when a replacement is available) or obtain replacements.

(6) Be sure that all push-button switches engage when pressed, disengage promptly when released, and lock if they are intended to lock.

(7) Be sure that all equipment markings or labels are clearly legible.

(8) Remove grease, oil, moisture, and other foreign matter from the controls and the area around the controls. Pay special attention to the recesses of push-button switches.

c. Check all meters, indicators, and limits.

(1) Inspect all meters to insure that the indicating needles are intact and straight, and that the needles move as they should. Check the movement of the needle when the set is turned on or when changes during operation affect the indication of the meter.

(2) Check the glass covers of all meters and indicators to insure that they are not cracked or loose.

(3) Check the jewels of pilot lights and illumination lights to insure that they are not cracked or loose.

(4) Check for condensed moisture on the inside of glass meter covers and light jewels. This is an indication of inadequate sealing of the equipment, inadequate ventilation, or both.

(5) Be sure that glass meter covers are not discolored. Wipe off any grease, oil, moisture, or other foreign matter that may have accumulated on the outer surface of the glass. Check the equipment manual for cleaning procedures.

(6) Be sure that meter faces are not discolored or mildewed.

(7) Be sure that all meters are zeroed before power is applied to the equipment.

(8) Be sure that all meter control and selector switches are in their specified positions before turning on power.

(9) Be sure that all mounting screws for meters and indicators are in place and tightened (if accessible from the exterior of the cabinet).

d. Check cases, covers, straps, and fasteners.

(1) Check the case and the cover of the set to insure that all latches, catches, handles, and attached straps and fasteners are in good condition and in place.

(2) Check the outside of metal cases and covers for dents, punctures, sharp edges, scratches, and missing or peeling paint.

(3) Check canvas or plastic covers or equipment bags for tears, mildew, dirt, grease, or moisture.

(4) Check all mounting screws, panel screws, shock mounts, and ground straps to insure that they are in place, tight, and in good condition.

(5) While the set is warming up, check the ventilation equipment for trouble-free operation and the free flow of air in the ducts. Insure that no foreign objects are placed where they can interfere with the ventilation of the equipment. If there is any indication that the ventilation of the set is not adequate, turn off the power until the cause of the trouble is determined and corrected.

(6) Inspect all accessories for completeness and cleanliness.

(*a*) Be sure that all headsets, handsets, microphones,

speakers, and keys are in serviceable condition, free from dirt, moisture, and other foreign materials.

(*b*) Be sure that cords and connectors are ready for use, free from breaks, corrosion, damaged insulation, kinks, and knots.

(*c*) Be sure that all accessories that are not to be used are stored, but available when needed.

e. Record on an appropriate maintenance form all deficiencies and shortcomings observed during inspections. Since the operator is directed to inspect a number of items for conditions that he is not authorized to correct, he must record these deficiencies and shortcomings on the appropriate maintenance form for action by authorized maintenance personnel. The operator should take immediate action to insure that the set will receive the maintenance or repair needed to keep it in operation.

187. Maintenance During Operation

Each radio operator must be trained to observe closely the operation of his equipment. He should pay particular attention to peculiarities in the operation of the equipment, and should investigate these peculiarities immediately. During operation of any radio set, the operator should—

a. Use the operational checklist in the appropriate equipment manual to check the equipment. Start the checks as soon as the set is warmed up and ready for operation.

b. Check the performance of the equipment by using specific settings of the controls and noting the results. Consult the equipment manual for specific settings. If the results are not normal, investigate to determine the fault or faults. If any fault is such that the operator is not authorized to take corrective action, record the results on the worksheet and report the condition to organizational maintenance personnel.

c. Check meters (if provided) for proper indications.

d. Check frequency indicators (if provided) to insure operation at the proper frequencies.

e. Check the modulation meter (if provided) for abnormal indicator changes.

f. Check the ventilation equipment periodically.

g. Check the set continuously for overheating. If there are indications of overheating, re-run the operational checks. If overheating is obvious, shut down the set as soon as possible and arrange to have organizational maintenance personnel trouble-

shoot the set. *This may not apply in a tactical situation, since continued use of the set may be sufficiently important to warrant the risk of damage to the set.*

h. Record deficiencies and shortcomings on the appropriate maintenance form, and report them to organizational maintenance personnel to expedite maintenance and repairs.

188. Maintenance After Operation

After-operation maintenance should start immediately after the circuit is closed, but before the set is turned off. In after-operation maintenance, the operator should—

a. Use the operational checklist in the equipment manual to check the set before it is shut down. Record any results that are not normal.

b. Turn off the set and perform the before-operation checks given in paragraph 186. Record deficiencies and shortcomings on an appropriate maintenance form.

c. Insure that all parts are lubricated.

d. Clean and service all components.

e. Clean, service, and store all cables, cords, minor components, and accessories.

f. Replace protective covers.

g. Make disposition of the set (combat readiness, standby storage, dead storage, forwarding to higher-category maintenance activity, etc.).

h. Report to organizational maintenance personnel all deficiencies and shortcomings found but not corrected.

Section IV. ORGANIZATIONAL MAINTENANCE

189. General

Organizational maintenance must be performed by personnel who have received training in the required skills, have demonstrated adequate ability in these skills after training, and have been properly authorized to perform organizational maintenance. It should be noted that *operator maintenance* and *organizational maintenance* are merely terms—they do not imply that a trained and skilled operator cannot be authorized to perform certain organizational maintenance duties. The terms are generally accepted indications of the levels of demonstrated ability that are required to qualify personnel to perform the duties. The actual

scope of organizational maintenance for any given radio set can be determined by referring to the equipment manual that covers the set.

190. Visual Inspection

Before operating a radio set that is not functioning properly, organizational maintenance personnel should inspect it visually for defects. This generally saves time and may prevent further damage to the radio set. The failure of many radio sets can be traced to one or more of the following faults:

a. Improperly connected power cords or cables.

b. Worn, broken, or disconnected cords or plugs.

c. Antenna lead-in improperly connected.

d. Receiver-transmitter interconnecting cable defective or not connected.

e. Defective tubes or crystals.

f. Loose or broken internal wiring.

g. Dirty or broken switch contacts.

191. Equipment Performance Checklist

Most equipment manuals contain an equipment performance checklist to provide a systematic troubleshooting technique. The equipment performance checklist is more detailed than the operational checklist and more technical in its scope. It is used to localize troubles to a chassis or to readily replaceable components. The equipment performance checklist is used in conjunction with the operational checklist to verify operators' reports of deficiencies and shortcomings, and to troubleshoot equipment. A typical equipment performance checklist is shown below.

Equipment Performance Checklist

	Step	Action	Normal indication	Corrective measures
PREPARATORY	1	Install desired antenna in antenna mount.		
	2	Connect H-138/U to either AUDIO connector.		
	3	Set VOLUME control at 5.		

	Step	Action	Normal indication	Corrective measures
EQUIPMENT PERFORMANCE	4	Set function switch at LITE.	Channel dial lights.	Replace BA-398/PRC-25. Replace dial lamp.
	5	Set function switch at ON.	Rushing noise is heard in H-138/U when no signal is received.	Connect H-138/U to other AUDIO connector. Check H-138/U by substitution. Replace BA-386/PRC-25. Check modules A16, A25, A21, and A5.
	6	Set function switch at SQUELCH.	Rushing noise is not heard in H-138/U.	Check module A24.
	7	Set up nearby AN/PRC-25 (known to be good) to transmit on a channel in 30- to 52-MC band and tune RT-505/PRC-25 to this channel. Obtain a long voice test signal from nearby AN/PRC-25.	Test signal is heard loud and clear.	If received test signal is weak, check antenna and antenna connection. If received test signal cannot be received at all, check modules A2 through A5, A9 through A15, and A17 and A18.
	8	Adjust a nearby AN/PRC-25 to transmit on channel in 53- to 75-MC band and tune RT-505/PRC-25 to this channel. Obtain long voice test signal from nearby AN/PRC-25.	Test signal is heard loud and clear.	Higher echelon repair required.
	9	Adjust nearby AN/PRC-25 to transmit on channels listed below. Obtain long voice test signal on each channel. Tune RT-505/PRC-25 to each channel in order given below: 30.00 MC 30.05 MC 30.10 MC 30.20 MC 30.30 MC 30.40 MC 30.50 MC 30.60 MC	Test signal is heard loud and clear on each channel.	Check following modules with the RT-505/PRC-25 tuned to channels which were not received: A10, A11, A12, A13, A14, A15, A17, and A18.

	Step	Action	Normal indication	Corrective measures
EQUIPMENT PERFORMANCE		30.70 MC 30.80 MC 30.90 MC		
	10	Adjust nearby AN/PRC-25 (known to be good) to receive test signals transmitted by RT-505/PRC-25. Press push-to-talk switch of H-138/U connected to RT-505/PRC-25 and send long voice test signal.	Test signal is heard loud and clear at nearby AN/PRC-25.	Check H-138/U by substitution. If signal cannot be received at all, check modules A1, A6, A7, A8, A22, and A23. Check tube V1. Check K1 and K3 by substitution. Tune nearby AN/PRC-25 to several channels on both sides of operating channel. If signal is received off channel, check A19.
	11	Adjust nearby AN/PRC-25 (known to be good) to receive test signals transmitted by RT-505/PRC-25. Set function switch of nearby AN/PRC-25 at SQUELCH. Press push-to-talk switch of H-138/U connected to RT-505/PRC-25 and send long voice test signal.	Test signal is heard loud and clear at nearby AN/PRC-25.	Check modules A23 and A24. Check K2 by substitution.
STOP	12	Set function switch at OFF.	Set stops operating.	Higher echelon repair required.

192. Electronic Test Equipment

Organizational maintenance personnel often are called upon to place new equipment into operation, perform routine preventive maintenance, or repair complex equipment. In most cases, the job cannot be performed without test equipment; in all cases, the job can be done more quickly, accurately, and efficiently if the test equipment is used properly. Common test equipment items include multimeters, signal generators, tube testers, frequency meters, and oscillators.

a. Multimeters. The multimeter is probably the most important single piece of test equipment available to maintenance personnel, since it can be used to make voltage, resistance, (and usually current) checks. The larger meters, which are normally used in higher echelon repair shops, are usually very accurate and fragile. The smaller meters are not as accurate as the larger meters but are of rugged construction for field use.

b. Signal Generators. A signal generator is a piece of test equipment that generates an AC signal that can be tuned through a large portion of the spectrum. This generated signal, which may be modulated or unmodulated, can be used for alignment of tuned circuits, dynamic troubleshooting (signal tracing), sensitivity measurements, field-intensity and stage-gain measurements, and signal substitution.

c. Tube Testers. To be of practical use in the field, a tube tester must provide a simple and quick appraisal of a tube. Tube testers accomplish this by comparing the condition of a specific tube with a predetermined standard.

d. Frequency Meters. Basically, a frequency meter is a tuned circuit with a dial that is calibrated directly in kilocycles or megacycles. The frequency meter is an accurate instrument used for frequency measurements and calibration of signal generators and receivers. Some types of frequency meters can be used in place of a signal generator for signal tracing or other troubleshooting procedures.

e. Oscilloscopes. The oscilloscope is an electronic instrument that provides a visual representation of one electrical voltage as a function of another on the screen of a cathode-ray tube. The main feature of the oscilloscope is its ability to portray graphically and instantaneously the fluctuating circuit conditions. Since the electron beam has negligible inertia, the cathode-ray tube responds to much higher frequencies than any other electrical indicating device.

193. Illustrations and Diagrams

Before attempting to troubleshoot a new or unfamiliar piece of equipment, organizational maintenance personnel should read all procedures and instructions in the organizational maintenance portion of the equipment manual. Special attention should be paid to the illustrations and diagrams.

a. Serious damage to equipment can be avoided if maintenance personnel are familiar with procedures used to remove a chassis from a case, panels from a chassis or a case, or components from

a chassis. Illustrations and diagrams in equipment manuals identify all parts and components, including mounting screws.

b. The illustrations and diagrams in an equipment manual indicate all test points, connectors, controls, and subchassis.

c. Equipment manuals provide schematic diagrams, partial schematic diagrams, and simplified schematic diagrams for use by maintenance personnel in making detailed checks of the circuit. If these diagrams are in the organizational maintenance portion of the manual, they may be used at that category of maintenance. If they are authorized for use by a higher category of maintenance, organizational maintenance personnel should ignore them. *No maintenance personnel are authorized to perform the maintenance duties of higher category maintenance personnel.*

d. Equipment technical manuals also provide tube base diagrams (for the proper category of maintenance) when a large number of electron tubes are used in a circuit. These diagrams indicate voltage and resistance readings from each pin to its ground.

194. Troubleshooting Procedure

Because of the wide variation in types of equipment in the field, there are no fixed rules for troubleshooting. The following are general procedures that will serve as a useful guide for organizational maintenance personnel until they learn, through experience, the best and quickest ways to obtain good results in troubleshooting.

a. Study the text, illustrations, and diagrams included in organizational maintenance instructions.

b. Review the operation of test equipments to be used.

c. Check the set in accordance with the procedures in the operational checklist.

d. Check the set in accordance with the procedures in the equipment performance checklist.

e. Perform the corrective measures given in the checklist.

f. Record any deficiencies and shortcomings that cannot be corrected immediately.

g. If maintenance of a higher category is required, forward the equipment, with maintenance records, to that shop. In some instances, direct support maintenance personnel make periodic visits to units that require their services. In this case, the records (or appropriate reports) are forwarded and the set is held (deadlined) until maintenance personnel arrive in the unit area.

If the set is urgently needed, immediate repair or maintenance may be requested on an emergency basis. This type of request should be avoided, if possible, since frequent requests for emergency maintenance will interfere with efficient operations at higher category maintenance shops.

195. Analysis for Corrective Action

Troubles in complicated electronic equipment, such as a radio set, are found by first locating the faulty unit in the system and then troubleshooting the unit. System troubleshooting requires an understanding of the interrelationship of the major components that make up a radio set. If trouble develops in one of the major components, the set cannot perform all of the functions for which it was designed. In some radios, a single fault may render a major component inoperative. Correction of this fault may be all that is needed to put the set back in operation. In other radio sets, the initial failure of one part, such as a capacitor, may cause failure of many other parts. In this case, all affected parts must be replaced before the radio set will operate.

a. To simplify the task of locating troubles, a radio set is subdivided into major components. In many cases, each major component is mounted on a separate chassis. In a representative radio system, the following are the major components:

(1) Transmitter.

(2) Receiver.

(3) Antenna system.

(4) Control unit.

(5) Power supply.

b. Each major component may depend, in some respects, on one or more of the other components. For example, the receiver will not operate if the antenna system or the power supply is faulty. Therefore, the fact that a component is not operating does not always mean that the trouble is in that component. The trouble may be in a unit that furnishes it an input signal or in the cabling that connects it to another unit. Thus, it is necessary to analyze carefully each situation in order to locate the component at fault. If this is not done, much time may be wasted in checking a component that is capable of normal operation.

c. A careful analysis of trouble also helps to prevent haphazard tampering with adjustments that will not improve overall performance and may possibly turn a minor repair problem into a major overhaul job. Maintenance personnel should follow

closely the specific methods for system troubleshooting in equipment manuals.

d. An analysis of the system should be followed immediately by a further analysis of the defective unit to locate the faulty part. A troubleshooting chart or a schematic diagram may be used to locate parts that might logically cause trouble.

CHAPTER 12

DESTRUCTION OF RADIO EQUIPMENT

196. General

In some tactical situations, it becomes impossible to evacuate all radio equipment. It is imperative, therefore, to destroy all equipment that cannot be evacuated to insure that it will not fall into enemy hands. Equipment captured by the enemy may be of use to him or may reveal information that was not previously known by him.

197. Destruction Priorities

a. Instructions for the destruction of equipment in the combat zone must be *adequate, uniform, and easily followed.*

b. Destruction of equipment must be as complete as time, equipment, and personnel will permit. Since the complete destruction of equipment will seldom be possible because of the time required, priorities must be established to insure that the higher classified items are destroyed first, followed by items of a lower classification. Unclassified items are destroyed last in the order of their importance to the enemy. All essential component parts must be destroyed on all similar sets to prevent the enemy from constructing one complete set from several damaged ones.

198. Destruction Plan

a. The destruction of equipment that is subject to capture will be accomplished only upon orders of the commander, and the destruction plan will be uniform throughout the command.

b. To provide uniformity all personnel must be familiar with the destruction plan, including the priority of destruction. In addition, they should be trained to use uniform procedures in destroying equipment.

199. Methods of Destruction

The methods of destruction outlined below will prevent the enemy from using, salvaging, or identifying a radio set.

a. Smash. Use sledges, axes, handaxes, pickaxes, hammers, crowbars, heavy tools, or other heavy objects to smash the crystals, tubes, meters, controls, headsets, dynamotors, microphones, storage batteries, relays, switches, resistors, dials, and coils.

b. Cut. Use axes, handaxes, machetes, or other sharp instruments to cut cords and wiring, and to rip out wiring from the chassis.

c. Burn. Use gasoline, kerosene, or oil to burn the technical manuals (or instruction books), diagrams, cords, wiring, carrying bags, and capacitors.

d. Bend. Bend the panels, cases, mast sections, and chassis.

e. Explode. If explosives are required in destruction work, use firearms, grenades, primacord, composition C, or TNT.

f. Break. Break all operating components, such as loudspeakers, headsets, microphones, and keys.

g. Dispose. Bury or scatter the destroyed parts in slit trenches, foxholes, or other holes; or throw them into streams or lakes.

APPENDIX I

REFERENCES

1. Publications

(C) ACP 110	Tactical Call Sign Book (U).
ACP 118(D)	Visual Call Sign Book.
(CM) ACP 121(C)	Communication Instructions General (U).
ACP 121(A)-1	Communications Instructions General.
(CM) ACP 122(B)	Communication Instructions Security (U).
(CM) ACP 124(B)	Communication Instructions, Radiotelegraph Procedure (U).
(CM) ACP 125(B)	Communication Instructions, Radiotelephone Procedure (U).
(CM) ACP 126	Communication Instructions, Teletypewriter Procedure (U).
ACP 129A	Communication Instructions Visual Signaling, Procedure.
ACP 131(A)	Communication Instructions — Operating Signals.
AR 105–31	Message Preparation.
AR 320–5	Dictionary of United States Army Terms.
AR 320–50	Authorized Abbreviations.
AR 380–5	Safeguarding Security Information.
AR 750–1	Concept of Maintenance.
DA Pam 108–1	Index of Army Motion Pictures, Film Strips, Slides, and Phono-Recordings.
DA Pam 310–1	Military Publications, Index of Administrative Publications.
DA Pam 310–3	Military Publications, Index of Doctrinal, Training, and Organizational Publications.
DA Pam 310–4	Military Publications, Index of Technical Manuals, Technical Bulletins, Supply Bulletins, Lubrication Orders and Modification Work Orders.
FM 21–5	Military Training.
FM 21–6	Techniques of Military Instruction.
FM 21–11	First Aid for Soldiers.

FM 21–30	Military Symbols.
FM 24–16	Signal Orders, Records and Reports.
FM 24–17	Tactical Communications Center Operation.
FM 24–20	Field-Wire Techniques.
TM 11–459	International Morse Code (Instructions).
TM 11–486–6	Electrical Communication Systems Engineering Radio.
TM 11–661	Electrical Fundamentals (Direct Current).
TM 11–662	Basic Theory and Application of Electron Tubes.
TM 11–665	CW and AM Radio Transmitters and Receivers.
TM 11–666	Antennas and Radio Propagation.
TM 11–668	FM Transmitters and Receivers.
TM 11–681	Electrical Fundamentals (Alternating Current).
TM 11–2651	Antenna Groups AN/GRA–4 and AN/GRA–12.
TM 11–5020	Antenna Equipment RC–292.
TM 38–660–1	Operation of Transportation Motor Pools and Driver Preventive Maintenance of Administrative Use Vehicles.
TM 38–750	The Army Equipment Record System and Procedures.
TM 38–750–1	Maintenance Management: Field Command Procedures.

2. Training Films

TF 11–1342	Tuning Transmitters—Part I: Setting Frequency.
TF 11–1632	The Effects of the Ionosphere on Radio Wave Propagation.
TF 11–1831	Tuned Circuits.
TF 11–1976	Radio Transmission Security.
TF 11–1995	Defense Against Radio Jamming.
TF 11–2069	Basic Principles of Frequency Modulation.
TF 11–2091	Tuning Transmitters—Part II: Amplifier and Antenna Tuning.
TF 11–1425	Preventive Maintenance Practices for Ground Signal Equipment.
TF 11–1776	Operation and Maintenance of Communication Equipment in Extreme Cold.
TF 11–2487	Radio Interference, Part I.

TF 11-2483	Radio Interference, Part II.
TF 11-2553	Radiotelephone Procedures, Operation.
TF 11-2851	Fundamentals of Radio Troubleshooting, Part I (Principal Technique).
TF 11-2852	Fundamentals of Radio Troubleshooting, Part II. Troubleshooting a Radio Receiver.
TF 11-2853	Fundamentals of Radio Troubleshooting, Part III. Troubleshooting a Radio Transmitter.
TF 11-2854	Fundamentals of Radio Troubleshooting, Part IV. Additional Devices and Techniques.

APPENDIX II

HALF-WAVE ANTENNA LENGTHS

1. Formula

The physical length of a half-wave antenna may be calculated by using the following formula:

$$L = \frac{468}{f}$$

where L is in feet and f is in megacycles. This formula does not apply to antennas longer than a half wave.

2. Table of Lengths

The following table gives the length in feet for half-wave antennas that are end-fed or center-fed. It is calculated in steps of one megacycle from 1 MC to 76 MC. The formula given in paragraph 1 may be used for frequencies that are not whole numbers.

Half-wave antenna lengths

Frequency (MC)	End-fed antenna (ft)	Center-fed antenna—for each side of insulator (ft)
1	468	234
2	234	117
3	156	78
4	117	58.5
5	93.6	46.8
6	78	39
7	66.8	33.4
8	58.5	29.2
9	52	26
10	46.8	23.4
11	42.5	21.2
12	39	19.5
13	36	18
14	33.4	16.7
15	31.2	15.6
16	29.2	14.6
17	27.5	13.7
18	26	13

Half-wave antenna lengths		
Frequency (MC)	End-fed antenna (ft)	Center-fed antenna—for each side of insulator (ft)
19	24.6	12.3
20	23.4	11.7
21	22.3	11.2
22	21.3	10.6
23	20.3	10.1
24	19.5	9.7
25	18.7	9.3
26	18	9
27	17.3	8.6
28	16.7	8.3
29	16.1	8
30	15.6	7.8
31	15.1	7.5
32	14.6	7.3
33	14.2	7.1
34	13.8	6.9
35	13.4	6.7
36	13	6.5
37	12.6	6.3
38	12.3	6.1
39	12	6
40	11.7	5.8
41	11.4	5.7
42	11.1	5.5
43	10.9	5.4
44	10.6	5.3
45	10.4	5.2
46	10.2	5.1
47	9.9	5
48	9.7	4.8
49	9.5	4.7
50	9.4	4.7
51	9.2	4.6
52	9	4.5
53	8.8	4.4
54	8.7	4.3
55	8.5	4.2
56	8.4	4.2
57	8.2	4.1
58	8.1	4
59	7.9	3.9
60	7.8	3.9
61	7.7	3.8
62	7.5	3.7
63	7.4	3.7
64	7.3	3.6
65	7.2	3.6
66	7.0	3.5
67	6.9	3.4

Half-wave antenna lengths		
Frequency (MC)	End-fed antenna (ft)	Center-fed antenna—for each side of insulator (ft)
68	6.8	3.4
69	6.7	3.3
70	6.6	3.3
71	6.5	3.2
72	6.5	3.2
73	6.4	3.2
74	6.3	3.1
75	6.2	3.1
76	6.1	3.0

APPENDIX III

TYPES OF EMISSION

Symbols are used to indicate the types of emission. These symbols (chart below) are used by the United States Government and Armed Forces and have also been adopted by many foreign powers. Damped waves, generally obsolete but occasionally encountered in foreign radio sets, are symbolized as type B emmissions.

Types of Emission

Type of modulation or emission	Type of transmission	Supplementary characteristics	Symbol
1. Amplitude	Absence of any modulation		A0
	Telegraphy without the use of modulating audio frequency (on-off keying).		A 1
	Telegraphy by the keying of a modulating audio frequency (or audio frequencies) or by the keying of the modulated emission (special case: an unkeyed modulated emission).		A 2
	Telephony	Double sideband, full-carrier	A 3
		Single sideband, reduced carrier	A 3a
		Two independent sidebands, reduced carrier	A 3b
	Facsimile		A 4
	Television		A 5
	Composite transmissions and cases not covered by the above.		A 9
	Composite transmissions	Reduced carrier	A 9c
2. Frequency (or phase).	Absence of any modulation		F 0
	Telegraphy without the use of modulating audio frequency (frequency-shift keying).		F 1

Type of modulation or emission	Type of transmission	Supplementary characteristics	Symbol
	Telegraphy by the keying of a modulating audio frequency (or frequencies) or by the keying of the modulated emission (special case: an unkeyed emission modulated by audio frequency).		F2
	Telephony	----------	F 3
	Facsimile	----------	F 4
	Television	----------	F 5
	Composite transmissions and cases not covered by the above.	----------	F 9
3. Pulsed emissions.	Absence of any modulation intended to carry information.	----------	P 0
	Telegraphy without the use of modulating audio frequency.	----------	P 1
	Telegraphy by the keying of a modulating audio frequency (or frequencies) or by the keying of the modulated pulse (special case: an unkeyed modulated pulse).	Audio frequency (or frequencies) modulating the amplitude of the pulse.	P 2d
		Audio frequency (or frequencies) modulating the amplitude of the pulse.	P 2f
	Telephony	Amplitude-modulated pulse.	P 3d
		Width-modulated pulse.	P 3e
		Phase- or position-modulated pulse.	P 3f
	Composite transmissions and cases not covered by the above.	----------	P 9

APPENDIX IV

JOINT ELECTRONICS TYPE DESIGNATION SYSTEM

1. Equipment Indicators

The type designation for a major equipment consists of an AN, a slant bar, a series of three letters, a dash, and a number (fig. 60). The AN indicates a major equipment; the first letter in the series of three letters indicates where it is used (installation); the second letter indicates what it is (type equipment); the third letter indicates what it does (purpose); and the number indicates the model number of the specific type. For example, AN/MRC-2 indicates model 2 of a mobile radio communications set. The AN indicates that it is a major equipment.

2. Component Indicators

The type designation of a component consists of one or two letters (see chart below), a dash, and a number. The letter or letters indicate the component, and the number indicates the model number. For example, RT-196 indicates the 196th model in the field of radio receivers and transmitters. If the component is part of, or is used with, a major equipment, you will have a longer type designation. For example, RT-196/PRC-6 indicates model 196 of a radio receiver and transmitter that is used with, or is a part of, model 6 of a portable radio communications set.

Indicator	*Meaning*
AB	Supports, Antenna
AM	Amplifiers
AS	Antenna Assemblies
AT	Antennas
BA	Battery, Primary Type
BB	Battery, Secondary Type
BZ	Signal Devices, Audible
C	Control Articles
CA	Commutator Assemblies, Sonar
CB	Capacitor Bank
CG	Cables and Transmission Line, RF
CK	Crystal Kits
CM	Comparators
CN	Compensators
CP	Computers
CR	Crystals
CU	Coupling Devices
CV	Converters (electronic)
CW	Covers
CX	Cords
CY	Cases
DA	Antenna, Dummy
DT	Detecting Heads
DY	Dynamotors
E	Hoist Assembly
F	Filters

Indicator	Meaning
FN	Furniture
FR	Frequency Measuring Devices
G	Generators
GO	Goniometers
GP	Ground Rods
H	Head, Hand, and Chest Sets
HC	Crystal Holder
HD	Air Conditioning Apparatus
ID	Indicating Devices
IL	Insulators
IM	Intensity Measuring Devices
IP	Indicators, Cathode Ray Tube
J	Junction Devices
KY	Keying Devices
LC	Tools, Line Construction
LS	Loudspeakers
M	Microphones
MD	Modulators
ME	Meters, Portable
MK	Maintenance Kits or Equipments
ML	Meteorological Devices
MT	Mountings
MX	Miscellaneous
O	Oscillators
OA	Operating Assemblies
OC	Oceanographic Devices
OS	Oscilloscope, Test
PD	Prime Drivers
PF	Fittings, Pole
PH	Photographic Articles
PP	Power Supplies
PT	Plotting Equipments
PU	Power Equipments
R	Receivers
RD	Recorders and Reproducers
RE	Relay Assemblies

Indicator	Meaning
RF	Radio Frequency Component
RG	Cables and Transmission Line Bulk, RF
RL	Reel Assemblies
RP	Rope and Twine
RR	Reflectors
RT	Receiver and Transmitter
S	Shelters
SA	Switching Devices
SB	Switchboards
SG	Signal Generator
SM	Simulators
SN	Synchronizers
ST	Straps
T	Transmitters
TA	Telephone Apparatus
TD	Timing Devices
TF	Transformers
TG	Positioning Devices
TH	Telegraph Apparatus
TK	Tool Kits or Equipments
TL	Tools
TN	Tuning Units
TS	Test Equipment
TT	Teletypewriter and Facsimile Apparatus
TV	Tester, Tube
U	Connectors, Audio and Power
UG	Connectors, RF
V	Vehicles
VS	Signaling Equipment Visual
WD	Cables, Two Conductor
WF	Cables, Four Conductor
WM	Cables, Multiple Conductor
WS	Cables, Single Conductor
WT	Cables, Three Conductor
ZM	Impedance Measuring Devices

EQUIPMENT INDICATORS			
1st Letter INSTALLATION	2d Letter Type of EQUIPMENT	3d Letter PURPOSE	Miscellaneous Identification
A -- Airborne (installed and operated in aircraft). B -- Underwater mobile, submarine. C -- Air Transportable (inactivated, do not use). D -- Pilotless carrier. F -- Fixed. G -- Ground, general ground use (include two or more ground type installations). K -- Amphibious. M -- Ground, mobile (installed as operating unit in a vehicle which has no function other than transporting the equipment). P -- Pack or portable (animal or man). S -- Water surface craft. T -- Ground, transportable. U -- General utility (includes two or more general installation classes, airborne, shipboard, and ground). V -- Ground, vehicular (installed in vehicle designed for functions other than carrying electronic equipment, etc., such as tanks). W -- Water surface and underwater.	A -- Invisible light, heat radiation. B -- Pigeon. C -- Carrier. D -- Radiac. E -- Nupac. F -- Photographic. G -- Telegraph or teletype. I -- Interphone and public address. J -- Electro-mechanical (not otherwise covered). K -- Telemetering. L -- Countermeasures. M -- Meteorological. N -- Sound in air. P -- Radar. Q -- Sonar and underwater sound. R -- Radio. S -- Special types, magnetic, etc., or combinations of types. T -- Telephone (wire). V -- Visual and visible light. W -- Armament (peculiar to armament, not otherwise covered). X -- Facsimile or television.	A -- Auxiliary assemblies (not complete operating sets) B -- Bombing. C -- Communications (receiving and transmitting). D -- Direction finder and/or reconnaissance. E -- Ejection and/or release. G -- Fire control or search-light directing. H -- Recording and/or reproducing (graphic meteorological and sound). L -- Searchlight control (inactivated, use G). M -- Maintenance and test assemblies (including tools). N -- Navigational aids (including altimeters, beacons, compasses, racons, depth sounding, approach, and landing). P -- Reproducing (inactivated, do not use). Q -- Special, or combination of purposes. R -- Receiving, passive detecting. S -- Detecting and/or range and bearing. T -- Transmitting. W -- Control. X -- Identification and recognition.	X -- Changes in. Y -- Voltage. Z -- Phase, or frequency. T -- Training. FM24-18-1-58

Figure 60. Equipment indicators.

APPENDIX V

TECHNICAL AND TACTICAL CONSIDERATIONS IN FIELD RADIO COMMUNICATIONS

1. General

There are a number of technical and tactical characteristics of radio sets that must be considered in field radio communications. Some of these characteristics that determine the use of particular sets in military communication are—distance range, frequency range, type of emission (voice or continuous-wave), installation (man-carried or vehicular), and capability of communication with other types of radio sets.

2. Distance Range

The transmission range of field radio sets normally is based on ground-wave distance. For any given radio set, this distance will vary with changes in operating frequency, location of radio station and antenna, type of terrain, method of emission, type of antenna, and power output. The operator can increase the ground-wave range of the set by using the lower operating frequencies, which are not attenuated as rapidly as higher frequencies; by changing from voice to continuous-wave operation; or by substituting a long-wire antenna for the short-range whip antenna. Because of the effect of these variables, it is impossible to specify an exact distance range for any set. The *rated* ranges are based on average ground conditions for a specific type of operation, such as CW versus voice or fixed versus mobile.

3. Frequency Range

In some sets, such as the AN/GRC–87 or AN/VRC–34, the frequency range of the receiver is exactly the same as the frequency range of the transmitter. In other sets, such as the AN/GRC–19, the frequency ranges of the transmitter and the receiver are different. If different type radio sets are to be used for intercommunication, their frequency ranges must be considered before an operating frequency is assigned.

4. Methods of Communication

Most AM field sets have provisions for transmitting and receiving voice or CW signals and some have radio teletypewriter (RATT) capability. In addition, some sets are capable of tone transmission, known as modulated continuous wave (MCW). This method of telegraph transmission sometimes improves the readability of signals under certain conditions of noise or interference. When MCW is employed, the beat frequency oscillator (BFO) circuit used for CW reception is not required.

a. Radiotelegraph, which includes both CW and MCW, provides comparatively slow transmission speeds and, in addition, requires specially trained operators who achieve proficiency only after lengthy training periods. In a CW net, the speed of operation is normally no faster than the speed of the slowest operator in the net. However, CW will provide greater distance range and more reliable communication under adverse conditions than any other method of radio communication.

b. The use of CW has been replaced largely by frequency-shift-keyed (FSK) radio teletypewriter (RATT) circuits. These circuits are capable of handling a greater number of messages than radiotelegraph.

5. Installation

Field radio sets can be further classified as portable, vehicular, transportable, and mobile. Portable sets are low-powered and operate from dry cells installed within the case of the radio set or from hand-driven generators. Vehicular sets usually are of the medium-power class and operate from an electromechanical power supply which, in turn, is energized by the vehicular battery. For example, the AN/GRC-87 or AN/VRC-34 may use a vibrator and the AN/GRC-19 uses an alternator—both powered by the vehicular battery. Transportable and mobile radio sets may be either medium- or high-powered. These sets usually are powered by gasoline engine-driven generators which may be man-carried or mounted in a trailer. To permit operation from a protected position, remote control equipments are frequently used with field radio sets.

6. Capability of Intercommunication

a. Generally, communication between different types of radio sets is possible only if the sets can transmit over the required distance, and if they possess overlapping frequency ranges, use

the same method of communication (voice or CW), and use the same type of modulation (AM or FM). A low-powered radio set with a rated distance range of approximately 1.6 KM cannot be used to communicate with a radio set 8 KM away, even though both sets are operating on the same frequency with the same type of modulation and emission.

b. Because of technical differences in operation, FM equipment cannot be used to communicate with AM equipment even though the distance ranges and operating frequencies may be similar.

c. If two radio sets use different methods of emission (one set uses voice, and the other set uses CW), they may not be able to communicate. CW signals are not audible in a receiver that is adjusted for voice reception. A separate circuit, the BFO, is provided with most communication-type receivers and must be switched on for reception of CW. If the receiver is not equipped with a BFO circuit, or if the circuit is not turned on or properly adjusted, CW reception is impossible unless the transmitter is capable of MCW operation.

d. In summary, several factors affect the ability of radio sets to intercommunicate. When a new or unfamiliar radio set is used, these factors must be considered by the communication officer in classifying the set and in determining its limitations and capabilities.

GLOSSARY

Absorption. Removal of energy from a radiated field by objects that retain the energy or conduct it to ground. Loss by absorption reduces the strength of a radiated signal.

Addressee. The activity or individual to whom a message is to be delivered.

Agency of signal communication. A facility that has necessary personnel and equipment to provide signal communication.

Amplification. The process of increasing the electrical strength of a signal.

Amplifier. A device used to increase signal power. It may consist of several stages or sections to obtain desired amplification.

Amplitude modulation (AM). The process of varying the amount of radiated power in the RF carrier in accordance with the variations of an AF wave.

Angle of incidence. The acute angle (smaller angle) at which a wave of energy strikes an object or penetrates a layer of the atmosphere or ionosphere.

Antenna. An electrical conductor, or system of conductors, used to transmit or receive radio waves.

Audible. Capable of being heard.

Array (antenna). An arrangement of antenna elements, usually dipoles, used to control the direction in which most of the antenna's power is radiated.

Audio frequency (AF). A form of acoustical energy that can be detected as sound by the human ear. The range of audio frequencies extends from 20 to 20,000 cycles per second.

Authentication. A security measure designed to protect a communication system against fraudulent messages.

Axis of communication. The line or route on which lie the starting position and probable future locations of the command post of a unit during a troop movement. The main route along which messages are relayed or sent to and from combat units in the field.

Band of frequencies. Range of frequencies between two specified limits.

Bandwidth. A section of the frequency spectrum required to transmit the desired information, whether visual, aural, or both.

Beat frequency. A frequency resulting from combining two different frequencies. It is usually equal to the sum of or the difference between the two original frequencies.

Beat-frequency oscillator (BFO). An oscillator used to generate a local signal, which is combined with an incoming unmodulated CW signal to produce a beat frequency that is audible. It is used for continuous-wave reception.

Carrier frequency. The frequency of an unmodulated radio wave.

Carrier wave. The RF component of a transmitted wave upon which an audio signal, code signal, or other form of intelligence can be impressed.

Channel. An electrical path over which transmissions can be made from one station to another.

Circuit. A communication link between two or more points.

Coaxial cable (concentric line). A transmission line consisting of two conductors, one inside the other, and separated by insulating material. The inner conductor may be a small copper tube or wire; the outer conductor may be metallic tubing or braid. Radiation loss from this type of line is practically zero.

Command Post (CP). The headquarters of a unit or subunit where the commander and staff perform their functions. In combat, this headquarters is often divided into echelons.

Communications center. A communications agency charged with the responsibility for receipt, transmission, and delivery of messages. It normally includes a message center, a cryptocenter, transmitting facilities, and receiving facilities.

Communication security. The protection resulting from all measures designed to deny to unauthorized persons information of value which might be derived from a study of communications.

Conductivity. The relative ability of a material to allow the flow or passage of an electrical current.

Continuous waves (CW). Radio waves having a constant amplitude and a constant frequency.

Counterpoise. A conductor or system of conductors used as a substitute for ground in an antenna system.

Coupling. The association of two circuits in such a way that energy may be transferred from one to the other.

Critical frequency. The highest frequency at which a given wave at any given time will, if transmitted vertically, be refracted to earth by a layer of the ionosphere.

Cross modulation. A type of cross talk in which the carrier frequency being received is interfered with by an adjacent carrier, so that the modulated signals of both are heard at the same time.

Cryptocenter. An establishment maintained for the encrypting and decrypting of messages.

Crystal. A natural substance, such as quartz or tourmaline, that is used to control the frequency of radio transmitters.

Cycle. One complete positive alternation and one complete negative alternation of an alternating current or voltage.

Date-time group (DTG). The date and time, expressed in digits and zone suffix, at which a message is prepared for transmission. The DTG is expressed as six digits followed by a zone suffix—the first pair of digits denotes the date, the second pair the hours, and the third pair the minutes.

Detection. The process of recovering the audio component (audible signal) from a modulated RF carrier wave.

Deviation. A term used in frequency modulation to indicate the amount by which the carrier frequency increases or decreases when modulated. It is usually expressed in kilocycles.

Dielectric. An insulator. A term applied to the insulating material between the plates of a capacitor.

Dipole antenna. An antenna having an electrical length equal to a half wavelength at the frequency for which it is designed. It may be a single conductor, or it may consist of two elements, whose total length is one half wavelength, separated by an insulator or an air space at the point of connection to the transmitter.

Discriminator. A circuit that has an output voltage which varies in amplitude and polarity in accordance with the frequency of the applied signal. It is used primarily as a detector in an FM receiver.

Distortion. The amount by which the output waveform differs from the input waveform. Distortion may exist in amplitude, frequency of phase modulation.

Diversity system. A system of radio communication in which a single received signal is derived from a combination of, or selected from, a plurality of transmission channels or paths. The system employed may include space diversity, polarization diversity, or frequency diversity. The diversity principle takes advantage of the fact that fading characteristics of a given signal generally vary widely, at any given instant, at different receiving antenna locations, and with different frequencies.

Double sideband transmission. That method of communication in which the frequencies produced by the process of modulation are symmetrically spaced, both above and below the carrier frequency, and are all transmitted.

Duplex operation. Duplex (or full duplex) operation refers to communication between two points, in both directions simultaneously.

Electromagnetic field. The field of force that an electric current produces around the conductor through which it flows.

Facsimile. The transmission of still pictures or printed matter by means of electrical impulses that are controlled by a photoelectric cell and reproduced at the receiver by a mechanical device.

Fading. Variations in the strength of a radio signal at the point of reception.

Frequency. The number of recurrences of a periodic phenomenon in a unit of time. In specifying the electrical frequency, the unit of time is the second, for example, the frequency is 15,000 cycles per second. Radio frequencies are normally expressed in kilocycles per second (KCS) at and below 30,000 KCS, and in megacycles per second (MCS) above this frequency.

Frequency distortion. Distortion that occurs as a result of failure to amplify or attenuate equally all frequencies present in a complex wave.

Frequency, lowest useful high (LUF). The lowest high frequency effective at a specified time for ionospheric propagation of radio waves between two specified points.

Frequency, maximum usable (MUF). The upper limit of the frequencies that can be used at a specified time for radio transmission between two points and involving propagation by reflection from the regular ionized layers of the ionosphere.

Frequency meter. A device that is calibrated to indicate the frequency of the radio wave to which it is tuned.

Frequency modulation (FM). The process of varying the frequency of an RF carrier wave in accordance with the amplitude and frequency of an audio signal.

Fundamental frequency. The lowest frequency of a complex wave.

Frequency, optimum traffic (FOT). The most effective frequency at a specified time for ionospheric propagation of radio waves between two specified points (commonly taken as 85 per cent of the monthly median value of MUF for the specified time and path).

Ground. A metallic connection with the earth to establish ground (or earth) potential.

Ground wave. A radio wave that is not refracted from the ionosphere.

Harmonic. An integral multiple of a fundamental frequency. (The second harmonic is twice the frequency of the fundamental.)

Hertz antenna. An antenna system in which the ground is not an essential part. Its resonant frequency depends upon its electrical length, which is approximately half the wave length.

Heterodyne. The signal produced by the action between two alternating currents of different frequencies in the same circuit. The frequencies alternately add and subtract to produce two beat frequencies that are the sum of, and difference between, the two original frequencies.

Image frequency. The carrier frequency of an undesired signal that is capable of combining with the frequency of the local oscillator in a superheterodyne receiver to produce the intermediate frequency of the receiver. The image frequency is either higher or lower than the frequency to which the receiver is tuned by an amount equal to twice the intermediate frequency.

Impulse. Any force acting over a comparatively short period of time.

Induction. The act or process of producing voltage by the relative motion of a magnetic field and a conductor.

Intensity. The relative strength of electrical, magnetic, or vibrational energy.

Interference. Natural or man-made radiation of electrical energy that causes difficulty in reception of signals.

Intermediate frequency (IF). The fixed frequency to which the principal amplifier of a superheterodyne receiver is tuned. The intermediate frequency is produced by beating the received

RF against the output of a variable frequency oscillator to produce a constant beat frequency.

Ion. An atom that has lost or gained one or more electrons and is therefore positively or negatively charged.

Ionosphere. Highly ionized layers of atmosphere existing between the altitudes of approximately 30 to 250 miles (48 to 402 KM).

Jamming. Deliberate interference intended to prevent reception of signals in a specific frequency band.

Keying. The breaking or interrupting of a radio carrier wave (either manually or automatically).

Limiter. The part of an FM receiver that eliminates all variations in carrier amplitude, thus removing all noise present in the carrier as amplitude modulation.

Local oscillator. An oscillator that is a part of the receiver and is used to generate an RF output which is combined with the incoming RF signal to produce an intermediate frequency.

Loop antenna. An antenna consisting of one or more complete turns (loops) of wire. It is designed for directional transmission or reception.

Marconi antenna. An antenna system in which the ground is an essential part.

Means of signal communication. A medium by which a message is conveyed from one person or place to another.

Message. Any thought or idea expressed in brief form or in plain or secret language, and prepared in a form suitable for transmission by any means of communication.

Micro. A prefix indicating millionths.

Modulated carrier. An RF carrier, the amplitude or frequency of which has been varied in accordance with the intelligence to be conveyed.

Modulation. The process of varying the amplitude or the frequency of a carrier wave in accordance with other signals to convey intelligence. The modulating signal may be an AF signal, a video signal (as in television), electrical pulses or tones to operate relays, etc.

Network. A system consisting of a number of designated stations connected with one another by any means of communication.

Originator. The command by whose authority a message is sent. The responsibility of the originator includes the responsibility for the functions of the drafter and releasing officer.

Power. The rate of doing work or the rate of expending energy. Unit of electrical measurement is the watt.

Radiate. To send out energy into space, as in the case of RF waves.

Radio channel. A band of adjacent frequencies having sufficient width to permit its use for radio communication.

Radio frequency (RF). Any frequency of electromagnetic energy capable of propagation into space. Radio frequencies are much higher than frequencies associated with sound waves.

Radio-frequency amplification. The amplification of a radio wave by a radio receiver before detection or by a radio transmitter before radiation.

Rear echelon. That part of a headquarters which is principally concerned with administrative and logistical matters.

Reflection. The turning back of a radio wave from an object or the surface of the earth.

Refraction. The bending, or change in direction, of a radio wave passing into a layer of atmosphere or the ionosphere. This effect will turn the wave back to earth if the angle of incidence is not too great.

Relay. A transmission forwarded through an intermediate station.

Saturation. The condition that exists in a circuit when the current, voltage, or power has reached maximum and cannot be increased by any normal action that controls the circuit.

Selectivity. The degree to which a receiver is capable of discriminating between the desired signal and all other signals.

Sensitivity. The degree of response of a radio circuit to signals of the frequency to which it is tuned.

Sidebands. The additional frequencies, both above and below the carrier frequency, produced as a result of modulation of a carrier.

Sideband power. The power contained in the sidebands. It is this power to which a receiver responds (not to the carrier power) when receiving a modulated wave.

Single sideband. A system of radio communication in which either the upper or lower sideband is removed from AM transmission to reduce the channel width and improve the signal-noise ratio.

Skip distance. The distances on the earth's surface between the points where a radio sky wave is successfully reflected and refracted between the earth and the ionosphere.

Skip zone. The space or region within the transmission range where signals from a transmitter are not received.

Static. Any electrical disturbance caused by atmospheric conditions.

Tone modulation. A type of transmission obtained by causing the RF carrier amplitude to vary at a fixed AF rate. When this type of transmission is keyed, it becomes modulated continuous wave (MCW).

Transmission line. Any conductor or system of conductors used to carry electrical energy from its source to its load.

Tuning. The process of adjusting a radio circuit so that it resonates at the desired frequency.

Unidirectional. In one direction only.

Wavelength. The distance traveled by a wave, normally expressed in meters, during the time interval of 1 complete cycle. It is equal to the velocity divided by the frequency.

Wave propagation. The transfer of electromagnetic or acoustical energy from one place to another through a suitable transmission medium.

Zero beat. The condition where two frequencies are exactly the same and therefore produce no beat (audible) note.

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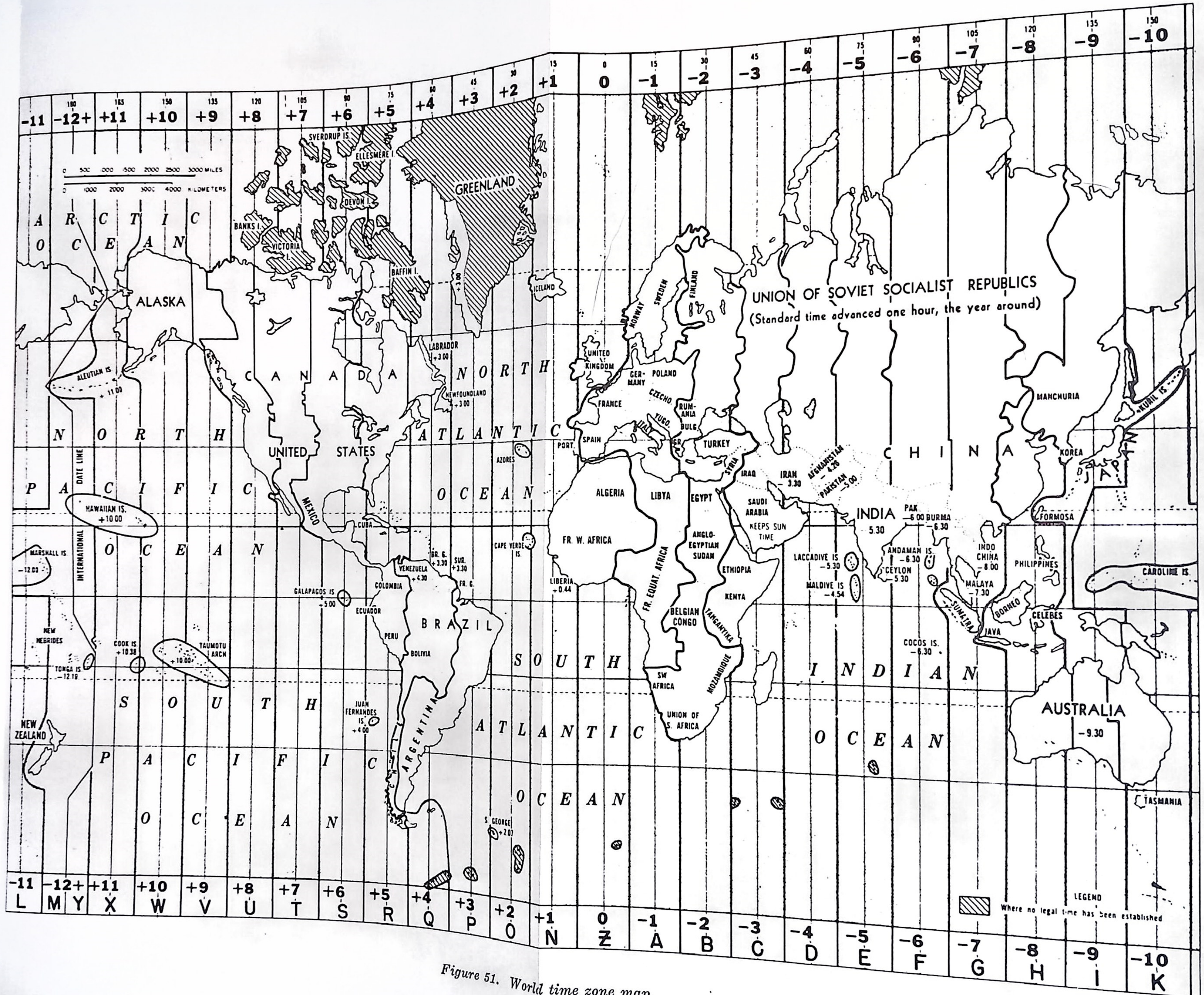

Figure 51. World time zone map.

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